Conneaut Lake
Watershed Implementation Plan
Crawford County, Pennsylvania

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1.0 Introduction and General Approach Towards Addressing the Watershed-Based Total Phosphorus Load

A Watershed Implementation Plan's worth cannot be realized without a strong local initiative to implement the actions outlined. It is critical that a plan be locally driven with an emphasis on leadership at the municipal and community level. The Conneaut Lake community will need to rely on the leadership and coordination of the Conneaut Lake Aquatic Management Association as well as each of the three municipalities within the watershed: Conneaut Lake Borough, Sadsbury Township, and Summit Township. Support for these efforts will be the responsibility of agencies and organizations including, but not limited to: Crawford County Conservation District, Crawford County Planning Commission, French Creek Valley Conservancy, as well as various other state and local agencies.

Conneaut Lake is Pennsylvania's largest natural lake, by surface area, at 947 acres (Appendix I), and is listed as a High-Quality, Warm Water Fishery (HQ-WWF). There are three public access areas to the lake: a PA Fish and Boat Commission boat launch, a public beach at the amusement park (Conneaut Lake Park), and Fireman's Beach operated by the Borough of Conneaut Lake. In addition, it is estimated that one million people visit and recreate at Conneaut Lake each year. These recreational activities include individual fishing, fishing tournaments, ice fishing, swimming, various water sports and boating. A variety of land-based activities are also enjoyed at Conneaut Lake; some of these activities include jogging, biking, golfing, camping, etc. In addition, there is an amusement park and an 18-hole golf course located on the northern portion of the lake, which are key components of the tourism industry.

While Conneaut Lake is a significant focal point for regional tourism it is not without serious water quality issues that threaten this use. The major impacts to the lake include high densities of the invasive aquatic plants Eurasian water milfoil (*Myriophyllum spicatum*) and fanwort (*Cabomba caroliniana*), the recent invasion of the exotic zebra mussel (*Dreissena polymorpha*), high rates of sedimentation and large algal blooms, particularly of blue-green algae (cyanobacteria). Ever since water clarity improved with the infestation of zebra mussels, the western shoreline of Conneaut Lake has experienced dense mats of benthic algae (*Mougeotia, Oedogonium, Spirogyra*) that break loose and wash up as rotting mats along the shoreline. There is also a large hydrilla (*Hydrilla verticillata*) infestation in Pymatuning Reservoir, only 8 miles west of Conneaut Lake. With boater movement between the two waterbodies on a daily basis, the threat of hydrilla infestation at Conneaut Lake is high.

Given the high recreational and economic value of Conneaut Lake to Crawford County and northwest Pennsylvania, as well as the importance of phosphorus in being one of the key causes of the observed water quality problems, the Pennsylvania Department of Environmental Protection (PA DEP) proposed and conducted a phosphorus-based Total Maximum Daily Load (TMDL) analysis of Conneaut Lake in 2001 (Appendix II). This TMDL quantified the magnitude of the phosphorus loads originating from agricultural lands as well as other sources (i.e. residential lands, on-site wastewater treatment systems, internal loading).

The TMDL was based on work conducted by Dr. Milt Ostrofsky in 1989 and the Phase I Diagnostic / Feasibility Study, which was conducted by select staff of Princeton Hydro in 1999 (back then a part of Coastal Environmental Services). The TMDL study was approved by the United States Environmental Protection Agency (US EPA) in 2001 and called for an approximately 40% reduction in the lake's annual total phosphorus load. In other words, the existing total phosphorus (TP) load needs to be reduced by 3,192 lbs in order to attain the targeted TP load.

Based on the TMDL, of the 3,192 lbs of TP that need to be removed from the annual TP budget of Conneaut Lake, 85% of this reduction is targeted to be removed by addressing the lake's internal phosphorus load. Based on the original Phase I Diagnostic / Feasibility Study, internal phosphorus loading (from the sediments) accounted for approximately 42% of the lake's annual TP load, being second only to surface runoff which accounts for slightly over half of the lake's annual TP load.

The Watershed Implementation Plan (WIP) developed herein will provide prioritized recommendations on addressing the external sources of TP but will also discuss how to address the internal source as well. The external (watershed based) TP load targeted for reduction is 479 lbs/yr as per the TMDL.

The development of this WIP for the Conneaut Lake watershed fits well with Pennsylvania's Non-Point Source (NPS) Management Program since it will directly address a variety of non-point sources of total phosphorus (TP) that impact the lake (stormwater, agricultural sources, internal loading). It also fits well with local objectives since it has a strong municipal-based strategy in the identification and prioritization of watershed-base projects for implementation. This WIP aims to reduce TP through a prioritized analysis of subwatershed TP loading and will address all nine (9) elements recognized by PADEP and USEPA as critical components for a successful Watershed Implementation Plan. Those nine (9) elements are as follows (Table 1.1):

Table 1.1: Watershed Plan Elements For Conneaut Lake Watershed Implementation Plan	Resulting Product (Section of Plan)
Preliminary Step – Characterize current status of the watershed, identify the primary pollutant of concern and determine what issues should be addressed through a watershed restoration plan.	Introduction
Preliminary Step – Revise and establish the watershed objective for the Conneaut Lake watershed through the characterization process and the water quality assessment.	Water Quality Monitoring, SAV and Updated Modeling
1. Identification of the **causes and sources** that will need to be controlled to achieve the load reductions estimated in this watershed-based restoration plan.	Watershed Site Assessment and Recommended BMPs
2. An estimate of the **load reductions needed to be achieved from management measures**, by source(s) listed in (1).	Introduction, Appendix
3. Description of the **NPS management measures** that will need to be implemented to achieve necessary load reductions and identification of critical areas in which those measures will be needed to implement the plan.	Watershed Site Assessment and Recommended BMPs
4. Estimate the amounts of **technical and financial assistance needed, associated costs, and/or the sources and authorities** that will be relied upon to implement the plan.	Technical and Financial Assistance
5. An **information/education component** that will be used to enhance public understanding of the project and encourage the public's early and continued participation in selecting, designing and implementing the NPS management measures.	Education and Outreach
6. A reasonably expeditious **schedule for implementing** the NPS management measures identified in the plan	Schedule and Milestones
7. Description of **interim, measurable milestones** for determining whether NPS management measures or other control actions are being implemented.	Schedule and Milestones
8. A set of **criteria that can be used to determine whether loading reductions are being achieved** over time and substantial progress is being made toward attaining desired water quality standards. If not attained, criteria for determining if the watershed-based plan needs to be revised.	Monitoring and Evaluation, Schedule and Milestones
9. A **monitoring component** to evaluate the effectiveness of the implementation efforts over time, measured again the criteria established in (8).	Monitoring and Evaluation

The following sections detail past studies, updated nutrient and hydrologic loading figures, and current water quality and SAV conditions. This database is utilized along with an updated watershed site assessment, subwatershed prioritization schedule and recommended BMPs to work towards the TMDL necessary load reduction of 479 lbs/yr of TP from watershed sources. Furthermore, educational objectives, scheduling, milestones and continued monitoring are discussed as they relate to the continued progress and measurable success of this program and those in the future.

2.0 Past Projects and Studies

The following section will provide a brief overview of some of the scientific work conducted on Conneaut Lake and best management practices (BMPs) that have been implemented in the watershed to date.

2.1 Studies

One of the earliest reports on Conneaut Lake was conducted by the US EPA under Working Paper Number 417 in 1975. This document was referenced by Dr. Milt Ostrofsky, of Allegheny College, and Jeffrey Owen, of the Crawford County Conservation District (CCCD), in their published study of the water quality and land use of the lake in 1989. This document included a study and description of the trophic state of the lake, computation of the phosphorus budget, an assessment of the paleolimnology of the lake and an examination of land use patterns in the watershed. Furthermore, management strategies for phosphorus mitigation were discussed. Much of the work related to the study of lake water quality as it relates to the trophic state and phosphorus dynamics have been continued by Dr. Ostrofsky in concert with the CCCD.

A Phase I Diagnostic / Feasibility Clean Lakes Study was conducted during 1999. This study collected a variety of in-lake water quality data, quantified the hydrologic and pollutant loads for the lake and developed a restoration and management plan for the lake and watershed. Funding for this project was provided by PA DEP under US EPA's Clean Lakes Program (Section 314 of the Clean Water Act). This study was subsequently utilized for the creation and adoption of the Total Maximum Daily Load which was prepared by the PA DEP in 2001.

2.2 Watershed Best Management Practices

A variety of watershed-based BMPs were implemented as part of earlier 319 NPS and PA Growing Greener Grant projects. These projects are summarized in the table below (Table 2.1). Princeton Hydro attempted to assess the nutrient removal capacity of the projects listed in Table 2.1 to update the amount of TP targeted for removal as part of the TMDL. The pollutant removal estimates are tentative given the scarcity of information related to these past projects. As such, these estimates should be vetted through the implementation of stormwater monitoring at these projects sites. Nevertheless, these estimates help in the assessment of the TMDL.

Table 2.1: Conneaut Lake – 319 BMPs

Site	BMP Type	BMP Size	P Removed per Year (Estimate)
			(lbs/yr)
Putnam & Brown Roads	Wetland	3 acres	0.5
Dicksonburg & Inlet Roads	Wetland	4.3 acres	4.8
	Fencing	1,100 ft.	
	Heavy Use Area	5,580 sq. ft	
	Roof Runoff	1 system	
	Spring Development	1 system	
	Underground Outlet	20 ft.	
McCarthy & Gibson Roads	Wetland	0.8 acres	21.5
	Fencing	5,784 ft	
TOTAL			**26.8**

As shown above, approximately 27 lbs/yr of TP are estimated to be removed from the previously implemented projects. This removal accounts for approximately 5.6% of the amount of watershed-based TP load targeted for reduction under the TMDL.

2.3 In-Lake Best Management Practices - Mechanical Vegetation Harvesting

Mechanical harvesting is a conventional aquatic plant control technique where specially designed machinery cuts, captures and removes aquatic plants from ponds and lakes, specifically submersed and floating leaved plants. The harvester does not completely remove the plants from the lake, as it only cuts the stems of aquatic plants, but it helps to remove large quantities of plant biomass from the lake. Harvesting removes the nutrients tied up within the biomass, preventing these nutrients from being recycled and re-used within the ecosystem.

Many of the shallower sections of Conneaut Lake are susceptible to the proliferation of nuisance densities of rooted aquatic plants. Given its size, the composition of its aquatic plant community, and its heavy and diverse recreational use, mechanical weed harvesting is the most cost effective and ecologically sound method of controlling nuisance weed densities at Conneaut Lake. Thus, the weed harvesting program has been in operation at Conneaut Lake since 1999.

The program has had varying degrees of success depending on operation schedules, ranging from harvest yields of 40 tons/year to 700 tons/year, with an inter-annual mean of approximately 400 tons/year. Removing this amount of biomass has had an impact on removing phosphorus and nitrogen stored in the plant tissues that would otherwise be released back into the lake upon plant senescence. Phosphorus and nitrogen removals were calculated by Dr. Ostrofsky and have been updated by Princeton Hydro as part of this project. Dr. Ostrofsky calculated a removal rate of approximately 0.000168 lbs/lb (169 mg/kg) of TP and 0.001763 lbs/lb (1,763 mg/kg) of TN (Ostrofsky, 1999). In contrast, Princeton Hydro collected composite samples of SAV and zebra mussel biomass from the lake during the survey conducted in 2016.

Plant / Mussel biomass samples were collected and sent to Environmental Compliance Monitoring of Hillsborough, NJ for analysis. The results revealed mean concentrations of 0.001083 lbs/lb (1,083 mg/kg) for TP and 0.0124 lbs/lb (12,400 mg/kg) for TN. The nutrients measured during this study, while remarkably higher than those measured by Dr. Ostrofsky, but were still lower than many measurements Princeton Hydro conducted for a similar study in Lake Hopatcong (Morris / Sussex Counties, New Jersey) where mean SAV TP concentrations were 0.002216 lbs/lb (2,216 mg/kg). The higher concentrations measured by Princeton Hydro may be due to the inclusion of zebra mussel biomass in the samples. Furthermore, the collection and subsequent analysis of these samples included any sediment or detritus contained within the plant matrix. As such, this analysis is a representative measure of what would be removed from a harvester under normal operation. Following lab analysis of plant nutrient content, Princeton Hydro assessed the annual harvest and corrected the reported annual harvest in wet weight to dry weight by assuming 8% of the harvested wet weight ended up as dry plant matter. This figure of 8% was derived by extensive work Princeton Hydro conducted for Lake Hopatcong that showed an average dry mass content of 8%. Next, the annual harvest, in dry weight, was multiplied by the nutrient content for TP and TN to compute annual removal via harvesting.

Phosphorus removal calculated by Dr. Ostrofsky ranged from 13 lbs to 236 lbs, averaging 134 lbs each year, while nitrogen removal ranged from 141 lbs to 2,469 lbs with an average of 1,407 lbs/year. Phosphorus removals calculated by Princeton Hydro ranged from a minimum of 7 lbs/year to 121 lbs/year with a mean of 69 lbs/year. Nitrogen removals calculated by Princeton Hydro ranged from 79 lbs/year to 1,389 lbs/yr with a mean of 792 lbs/year.

2.4 Street Sweeping

The Conneaut Lake Borough is the most urbanized portion of the Conneaut Lake watershed and contains a high percentage of impervious surfaces. Increasing amounts of impervious cover are often associated with increased pollutants. More highly populated areas also have more trash that ends up along the streets. There are various street sweeping technologies that provide different sediment and nutrient reduction rates. The Conneaut Lake Borough employs the use of a mechanical broom sweeper to clean the streets of the Borough.

Specifically, a Pelican HH Street Sweeper is used to clean the streets of Conneaut Lake Borough. The streets are typically swept three to four times a year, and once directly after winter. Overall, this street sweeper cleans 9.8 miles of street total each run. This practice yields approximately 10 cubic yards of waste per year. This waste includes leaf waste, branches, road sand and garbage that has collected along the streets of Conneaut Lake.

Through the use of street sweeping as a BMP measure, nutrient and sediment loads are removed prior to entering the lake, as a watershed-based proactive measure. Street sweeping reduces approximately 2 lbs TP, 5 lbs TN, and 600 lbs TSS from entering the Conneaut Lake ecosystem per year. This practice removes approximately 0.4% of the required watershed-based TP load targeted under the TMDL and should be continued.

3.0 Updated Watershed Pollutant Load and Subwatershed Prioritization

The pollutant load of Conneaut Lake was initially computed as part of a Phase I Diagnostic-Feasibility Study conducted by Coastal Environmental in 1999. This effort utilized the Unit Areal Loading Model in addition to empirical nutrient data collected by Dr. Milt Ostrofsky to compute the phosphorus, nitrogen and sediment loads to the watershed. These loading figures were subsequently utilized by the PADEP for the initiation of a TMDL in 2001. The phosphorus loading derived from the UAL modeling effort, as listed in the TMDL, is 7,673 lbs/yr. A brief summary of the sources of this annual load are listed in Table 3.1.

Table 3.1: Conneaut Lake TP TMDL

TP TMDL (lbs/yr)	
Source	**TP**
Watershed Runoff	4,087
Precipitation on Lake	351
Internal Loading	3,021
Groundwater	214
Sum	7,673
Target	4,630
Reduction	40%

Of this load identified in the TMDL, load reductions derived from certain sources (e.g. Atmospheric) or land use types (e.g. forest) was deemed not practical. Ultimately, the goal of this WIP is to provide **watershed** based BMPs which will reduce the annual TP load by 479 lbs. As guidance to this effort, the following section will provide a more detailed assessment of watershed-based pollutant loading as computed through the utilization of *Mapshed*. Nevertheless, loading reductions stated in the TMDL will remain as the guide points due to the regulatory importance of this document.

3.1 Mapshed Introduction

The interconnectivity between streams and their watersheds is a central tenet in non-point source (NPS) pollution control. Watershed size and the land uses, soil types, topography and geology in concert with variable climatic conditions all influence the quantity of water, its temporal distribution and the nutrient load entering receiving waterways. A direct correlation exists between watershed disturbance and increased nutrient loading. The conversion of forests to agricultural, residential, commercial and industrial lands brings about an increase in nutrient loading due to increases in erosion and a multitude of anthropogenic factors.

The modeling of NPS pollution on a watershed wide scale is a tedious task due to large spatial and temporal variations which must be considered, in addition to the large amount of data that must be compiled, integrated, analyzed and interpreted (Evans, 2014). Geographic Information Systems (GIS) have been utilized to integrate watershed simulation models in order to increase computational efficiency and accuracy of complex hydrologic and pollutant transport calculations. *MapShed* is a GIS-based watershed modeling tool that essentially duplicates the functionality of a similar software application previously created by the Penn State Institutes of Energy and the Environment called AVGWLF (Evan, 2014). The GIS interface for *MapShed* uses the freeware GIS software package *MapWindow*. *MapShed* provides a link between the GIS software and an enhanced version of the GWLF watershed model. As with AVGWLF, the watershed simulation tools used in *MapShed* are based on the GWLF model originally developed by Dr. Douglas Haith and colleagues at Cornell University.

The GWLF model provides the ability to simulate runoff, sediment, nitrogen and phosphorus loads from a watershed given variable size-source areas. It also has algorithms for calculating septic loads and allows for the inclusion of point source nutrient loading. GWLF is a continuous simulation model that utilizes daily time steps for weather data and water balance calculations. Monthly calculations are made for nutrient and sediment loads based on the daily water balance accumulated monthly values. GWLF is considered to be a combined distributed / lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows for the inclusion of multiple land use scenarios but each area is assumed to be homogenous in regard to various attributes considered by the model. In addition, the model does not spatially route watershed transport of sediments and nutrients but simply aggregates loads from each source area. For sub-surface loading, GWLF acts as a lumped parameter model using a water balance approach. No distinct areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated sub-surface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration (Evans 2014).

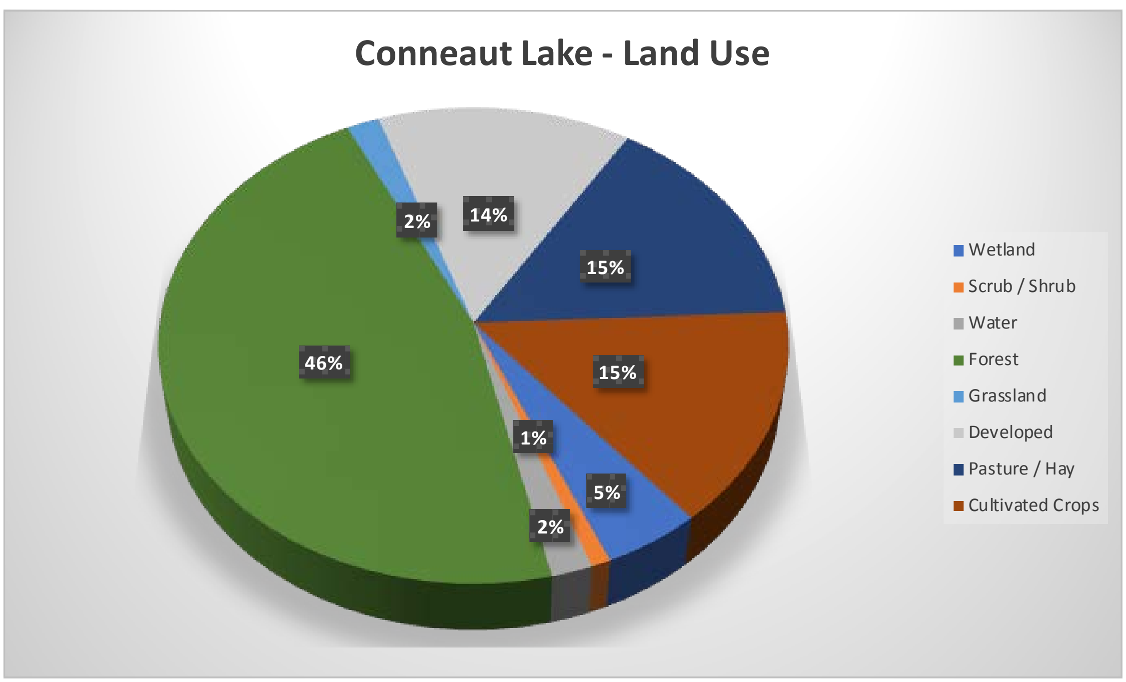
Hydrologic loading is simulated through the GWLF model utilizing the Soil Conservation Service – Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) as inputs. Erosion and sediment yield are estimated utilizing monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of the KLSCP values for each source areas (LU/LC combination). A sediment delivery ratio based on watershed size and a transport capacity average daily runoff is then applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural land use source area. Point sources, manured areas and septic systems are also integrated into nutrient loading calculations as the latter two sources may provide a significant nutrient and fecal coliforms source in more rural areas. Urban nutrient inputs are assumed to be solid-phase and are modeled utilizing an exponential accumulation and washoff function. Sub-surface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads while the sub-surface sub-model considers a single, lumped parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent upon LU/LC. Finally, a water balance is performed utilizing supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage and evapotranspiration values (Evans, 2014).

Princeton Hydro utilized *Mapshed* as the primary modeling tool to compute the hydrologic and pollutant load for Conneaut Lake. The following section details the results of the *Mapshed* modeling effort which includes the hydrologic balance for the watershed in addition to the sediment, nitrogen and phosphorus load derived from the watershed as an aggregate and as broken down into nine (9) sub-watersheds. These data will be utilized as a comparison to the loading estimates conducted in the Phase I study and towards the recommendation of BMPs throughout the watershed aimed towards TP reduction.

3.2 Mapshed Results

The Conneaut Lake watershed is approximately 16,227 acres. Land use breakdowns for the watershed are depicted in Figure 3.1.

Figure 3.1: Conneaut Lake – Land Use



Dominant land use in the watershed is forest which comprises 46% of the total area. Pasture / hay and cultivated crops are tied for the second greatest land use in the watershed at 15% each while developed lands, including developed open space and various density housing, comprises 14% of watershed area. The TP load originating from the developed lands, including residential, developed open space and agriculture will be the focus for management as the loading from forested areas and other 'natural' land-uses is deemed not suitable for control.

Cumulatively, 1.18 x 10^9 ft^3 of water enters Conneaut Lake per year. The monthly breakdown of streamflow to the lake is provided in Figure 3.2 while components analysis of this streamflow is presented in Figure 3.3.

Figure 3.2: Conneaut Lake – Annual Streamflow

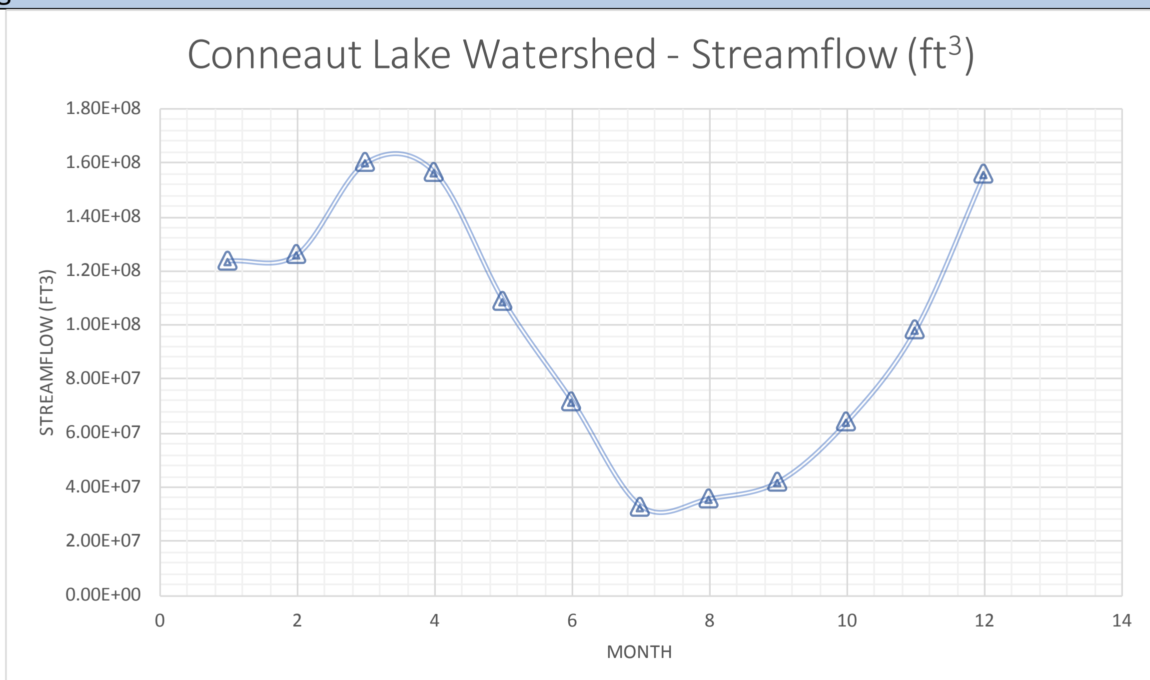
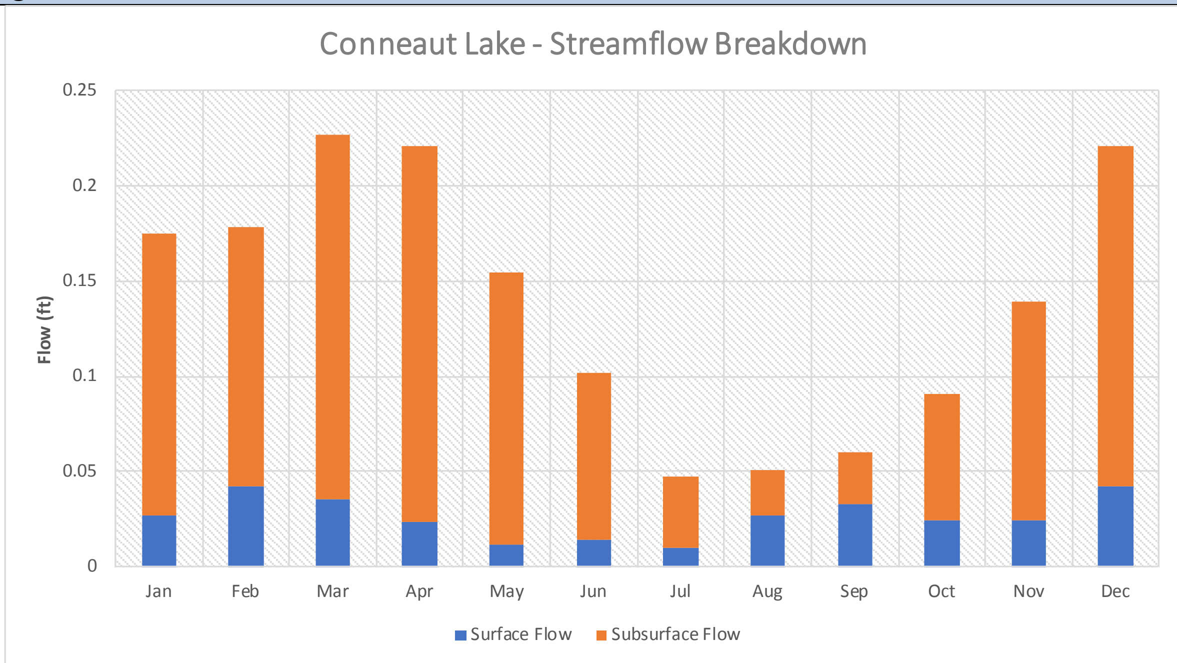


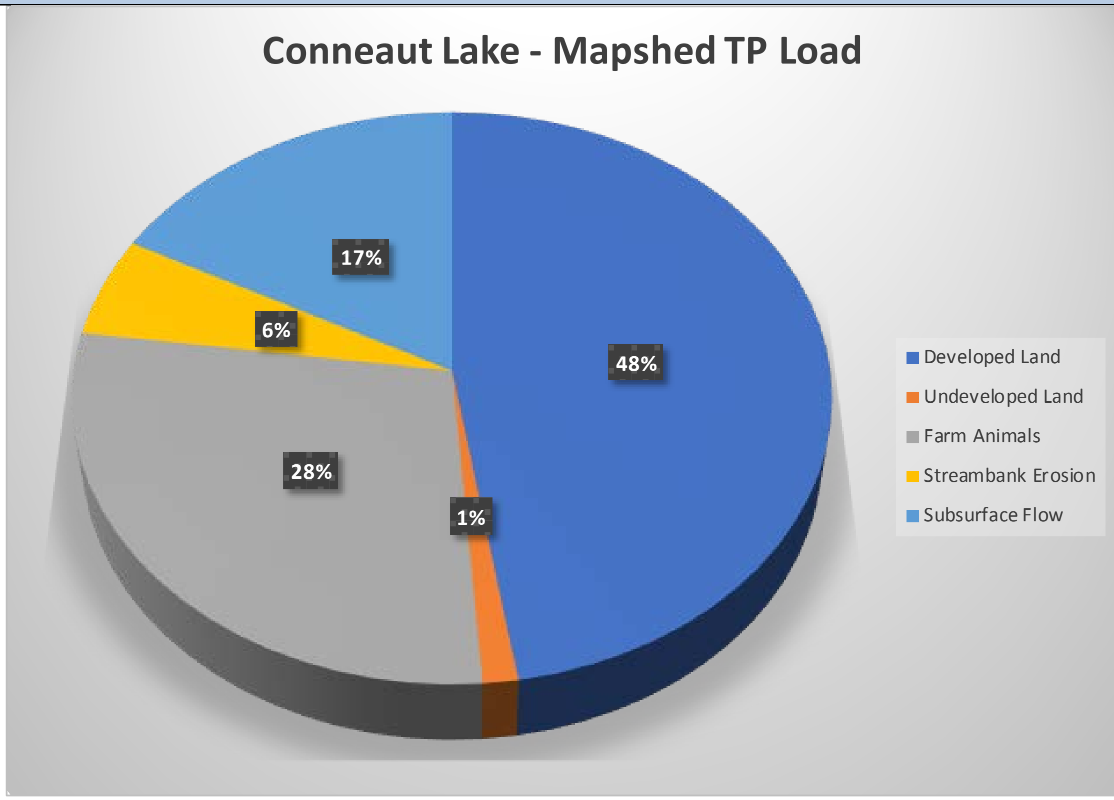
Figure 3.3: Conneaut Lake – Annual Streamflow



As shown above, Streamflow reaches a peak in March and April associated with snowmelt, increasing spring rains and a lack of strong evapotranspiration which is associated with leaf out. Streamflow declines as the growing season progresses with minimal streamflow in July and August. Streamflow again increases reaching a secondary peak in December. Streamflow components are comprised of surface runoff and subsurface groundwater flow. Subsurface flow comprises the majority of streamflow to the lake with peak contributions in March, April, May and again in November and December. Surface Runoff comprises a larger portion of the streamflow hydrograph during August and September (Figure 3.3).

Annual loading of sediment, nitrogen and phosphorus to the lake is 3,788,493 lbs, 60,084 lbs and 5,768 lbs, respectively. Source areas of phosphorus to the lake are presented in Figure 3.4.

Figure 3.4: Conneaut Lake – TP Source Areas



The Mapshed modeled external TP load of 5,768 lbs/yr is greater than that calculated as part of the Phase I study which was 4,301 lbs/yr (Watershed + groundwater only). The greatest source of external TP, as calculated with the Mapshed model, was developed land which comprises 48% of the external load. For this analysis, developed land includes residential and agricultural land uses. Farm animals were the second greatest source of TP to the lake where they account for 28% of the total annual load. Estimates of farm animal densities are based on county-level farm animal populations sourced from the United States Department of Agriculture (USDA) and are weighted by 'farmland acres' for this watershed. Subsurface groundwater sources of TP were the third highest contributor associated with 17% of the total phosphorus load.

3.3 Subwatershed Prioritization

The Conneaut Lake watershed boundaries were delineated into sub-watersheds for the Mapshed analysis. For the sake of consistency, these nine (9) sub-watersheds followed the same boundaries that were delineated during the original Phase I study. Nutrient loading for these sub-watersheds were computed utilizing Mapshed in the same manner that was conducted for the watershed as an aggregate. Following modeling, phosphorus loads were parsed into 'Developed' and 'Undeveloped' loads. The developed loads included land use derived loading from residential and agricultural lands, farm animals and stream bank erosion. Undeveloped loads included subsurface groundwater, forested land and wetlands. These loads were tallied then normalized for developed and undeveloped land area to develop loading coefficients for each subwatershed. These loads were subsequently ranked for prioritization of NPS loading reduction.

It should be emphasized that the prioritization of the sub-watersheds based on their developed TP loads serves as a guidance tool to aid in making management and planning decisions on the selection of restoration sites (Section 4.0). Therefore, extenuating issues such as property ownership, availability of easement acquisition, roadway ownership, environmental constraints (e.g. wetlands, steep slopes, shallow depth to bedrock) and design and implementation costs all need to be taken into account when final decisions on the selection of project sites are made. However, the data presented here is a site-specific and objective strategy in continuing the TMDL-based long-term restoration and management of Conneaut Lake.

Subwatershed-based loading of total phosphorus is depicted in Table 3.2. This load is broken down for Developed and Undeveloped land and will be the basis for the prioritization of subwatershed for NPS reduction measures.

Table 3.2: Conneaut Lake – Subwatershed TP Loading

Conneaut Lake - Subwatershed TP Ranking

Subwatershed	Developed TP Load (lbs/acre)	Priority
4	0.88	High
3	0.81	High
2	0.69	Medium
5	0.65	Medium
8	0.61	Medium
1	0.58	Medium
9	0.28	Low
6	0.20	Low
7	0.16	Low

4.0 Candidates for Best Management Practices

The following section details various sites that have opportunities for watershed-based BMP implementation. Each section lists current site conditions, the recommended BMPs and an estimate of the pollutant removal from each BMP. These removal rates are estimates based on BMP type and removal rates listed in the Pennsylvania Stormwater BMP Manual (2006). Section 5 (below) provides recommendations for in-lake nutrient reduction measures while Section 6 summarizes the cost, pollutant removal and maintenance for each measure. A figure depicting the location of each BMP is provided in Appendix I.

4.1 Borough of Conneaut Lake

4.1.1 Site 1 – Maintenance Parking Lot – Subwatershed 1

Located at the corner of North 3rd Street and Church Lane within Conneaut Lake Borough is the Conneaut Lake Borough maintenance building. A gravel parking lot is located directly next to the building, as well as a mowed lawn and roads. There is a grate at the edge of the parking lot, as well as a swale across the street that collects stormwater from the adjacent areas. The swale leading to the parking lot is mowed, without any other vegetation. This area is in close proximity to Conneaut Lake, and is an acute source for stormwater inputs. This property is owned by the Conneaut Borough.

<u>Recommendations</u>: A three-chambered baffle box manufactured treatment device (MTD) could be installed within the parking lot at this property to help filter out particulates from the road runoff, lawns and inputs from the swale leading up to this area. The swale leading to the parking lot could be vegetated with native species and retrofitted to allow for more stormwater interception. By introducing these BMPs in series, solids and then dissolved nutrients can be removed prior to entering the lake.

Conneaut Lake Borough is the most developed area within the entire watershed. Incorporating a MTD into the parking lot will reduce solids and associated phosphorus to the lake. It is projected that an MTD will decrease the annual TP load within the borough by 12.4 lbs/year. A swale across the road leads to the proposed site. Naturalization of this swale through possible soil amendment and planting of native vegetation may remove an additional 16.3 lbs of TP/year. In summation, this single site retrofit could decrease TP loading by 28.7 lbs/year. Furthermore, TSS loading would be decreased by 19,252 lbs/year and TN would be decreased by 121 lbs/year.

The following Figure (4.1) depicts the current site while Figures 4.2 through 4.4 provide graphical examples of three-chambered baffle box BMPs and an illustrated example of a bioswale.

Figure 4.1: Conneaut Lake Borough Maintenance Parking Lot

Three-chambered baffle boxes work by intercepting stormwater into a series of concrete baffles. These baffles work to dissipate energy and allow solids and their attached nutrients to sink to the bottom. Cleaner water exits the system via the outflow pipe. Baffle boxes may be modified for site specific conditions through the inclusion of hydrocarbon filtering media or similar material. Maintenance to the systems is conducted through the access hatches which allow for easy access for pump-out utilizing a standard vacuum truck.

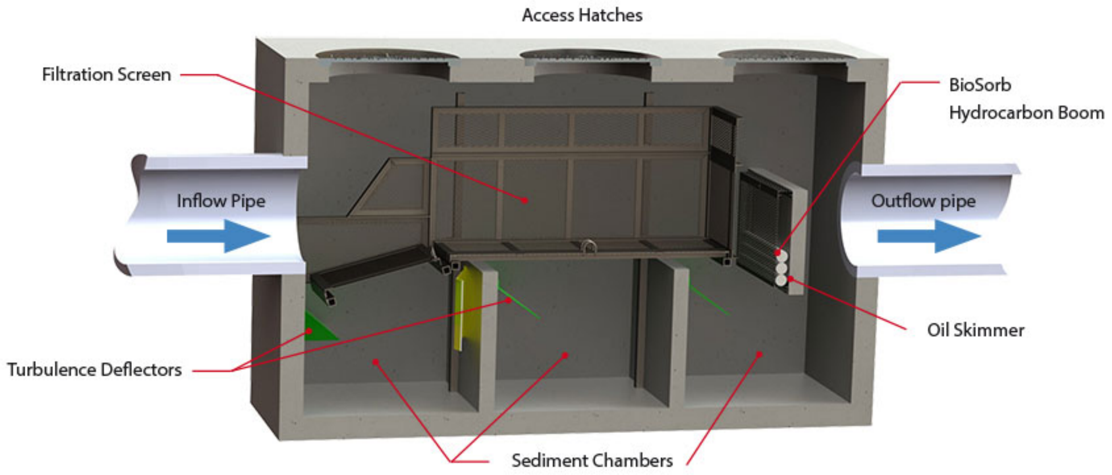
Figure 4.2: Three-chambered baffle box MTD Example

Source: BioCleanEnvironmental

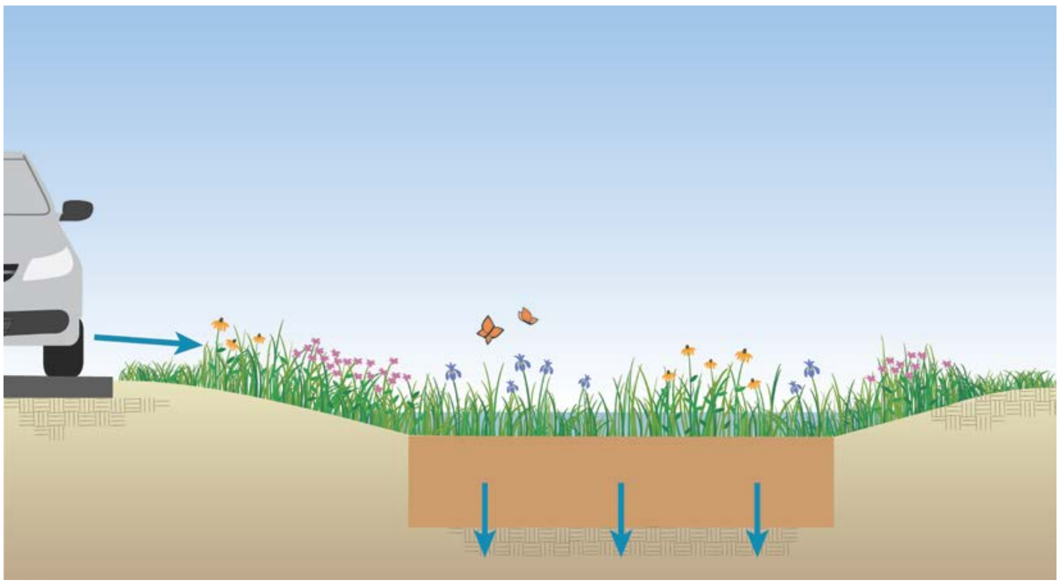
Figure 4.3: Three-chambered baffle box MTD Installed

Source: Suntree Technologies

Bioswales are engineered stormwater conveyance systems which serve to intercept stormwater, slow and dissipate energy and settle solids. They are often constructed with amended soil, native vegetation and, if needed, an underdrain. Pollutant removal occurs through the settling of solids in the system and uptake of nutrients through plants or the microbial community residing in the soils or on plant roots.

Bioswales may be utilized in a treatment train where the discharge from a MTD would then flow through the bioswale. Hydrologic input to a standalone bioswale may exit the system as surface outflow or entirely through groundwater replenishment via infiltration.

Figure 4.4: Bioswale Example



Implementation of the BMPs recommended for site 1 would likely occur in partnership with the Conneaut Lake Borough and the Conneaut Lake Aquatic Management Association. Funding for this project may possibly be obtained through PA DEP Growing Greener grant program or through US EPA 319 funding for non-point source nutrient control.

4.2 Sadsbury Township

4.2.1 Site 2 – Iroquois Road – Subwatershed 9

Located along the southeastern shore of Conneaut Lake. This road has two swales leading along each side of the road towards the lake, which are then piped from Cayugo path to the lake. For the majority of the street, the swales have low flow concrete channels.

Recommendations: Remove the low flow concrete channels along the sloped hill and replace with a vegetated swale with check dams or step-pool conveyance system. One or two baffle boxes or similar MTDs are recommended along the roadside at some point before entering the lake where stormwater piping infrastructure is present. The owners of the property at the intersection of Cayugo and Iroquois (Figure 4.5) would likely be open to construction on their property. There are multiple options for MTD installation (dependent on right of ways and easements). The MTDs will act as a terminus pollutant control points before flow enters Conneaut Lake.

Retrofitting the current low flow channels into a natural vegetated swale will provide a higher capacity for the treatment of stormwater pollution. Stormwater will be filtered by the vegetation and infiltrate into the soil, removing nutrients and sediment before entering the lake. By re-designing these swales, pollutant reductions of TP 1.6 lbs/year, TSS 1,624 lbs, and TN 4.5 lbs/year are estimated.

A MTD of some sort is recommended for this site as well. A nutrient-separating baffle box or other MTD will help further decrease the amount of TP and TSS loads from the watershed. Between the swale retrofits and the MTD, loads will decrease by: TP 2.8 lbs/year, TSS 3,929 lbs/year, and TN 11 lbs/year.

Figure 4.5: Sites along Iroquois Road

The implementation of stormwater upgrades for site 2 would likely include Sadsbury Township with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

4.2.2 Site 3 – Konneyaut Trail – Subwatershed 9

Located along the southeastern shore of Conneaut Lake on Konneyaut trail (Figure 4.6). Along this street, mowed swales appear along both sides. Many of the inlets and outlets have riprap to slow the flow and sediment. This area is inundated with high amounts of stormwater due to various flooding issues. The swale on the east side of the road is much broader then the swale on the west side.

Recommendations: Swales on each side of the road could be modified into step-pool conveyance systems to slow surface flow, allow it to infiltrate and filter / reduce sediments and nutrients. Otherwise, planting native vegetation and check dam type structures could help to slow discharge and reduce sediment and nutrient loading.

Improving on the existing swale by vegetating and updating riprap/storage will help attenuate and infiltrate stormwater. Nutrients and sediment can settle out prior to entering the lake. Through these retrofits, TP loads would decrease by 1.2 lbs/year, TSS would reduce by 1,119 lbs/year, and TN would decrease by 4 pounds/year.

Figures 4.6: Swale Condition at Konneyaut Trail

Partnerships for implementing stormwater upgrades for site 3 would include Sadsbury Township with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

4.2.3 Site 4 – Seneca Road – Subwatershed 9

This site is located in the southeastern most portion of the lake, adjacent to Nye's Marina Service. The section of the lake by this street has a large amount of sediment buildup. Adjacent to one of the homes, is a mowed basin with an outlet structure already in place. A large amount of runoff also comes from Mohawk Road which is a dirt and gravel road upgradient from Seneca Road (Figure 4.7). There is a swale on either side of Seneca Rd leading down to the lake. This swale is currently not vegetated.

Recommendations: Retrofit the basin into a vegetated biofiltration basin (Figure 4.8). The swale should be regraded if necessary and planted with native vegetation for greater and more efficient interception or integrated as a step-pool conveyance system. Install a MTD such as a baffle-box prior to or below the swale that can further filter stormwater.

By retrofitting the basin located at this site into a naturalized dry extended detention basin, stormwater will undergo greater infiltration into the underlying soils and dissolved nutrients will be assimilated by the native vegetation. Retrofitting the existing swale will also improve stormwater quality. Installing an MTD prior to the swale to further filter runoff before entering the lake. With the installation of these three BMPs, external loading would be reduced by: TP 3.1 lbs/yr, TSS 3,665 lbs/yr, and TN 15 lbs/year.

Figure 4.7: Conditions at Seneca Rd

Figure 4.8: Vegetated Basin Retrofit Example

Source: Princeton Hydro – Carnation Basin Retrofit

Partnerships necessary for implementing stormwater upgrades for site 4 would include Sadsbury Township with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

4.2.4 Site 5 – Foust Road – Subwatershed 9

This area is adjacent to Conneaut Lake Sand and Gravel mine, and experiences runoff from the site. It contains a small swale along each side of the road running down the hill towards the lake (Figure 4.9). These swales eventually lead to the unnamed tributary that connects to Midway Beach.

Recommendations: Install an MTD, such as a three-chambered baffle box, at the bottom of Foust Road to help reduce sediments/gravel and nutrients from further entering the lake. Improve upon the current swales through stabilization and/or planting of native vegetation.

Installing a MTD at the bottom of Foust Road would be beneficial to help reduce nutrients and sediments from entering the stream directly adjacent to it. Foust Road is downgradient from mine runoff as well as some cropland. Along with a MTD, there are road side swales that could be improved with native vegetation and re-grading. Through the combination of these retrofits the nutrient loads will decrease by: TP 9.3 lbs/year, TSS 11,875 lbs/yr, and TN 87 lbs/year.

Figures 4.9: Site conditions at Foust Road

Partnerships for implementing stormwater upgrades for site 5 would include Sadsbury Township with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

4.2.5 Site 6 – Conneaut Lake Sand & Gravel Mine – Subwatershed 9

Due to the glacial formation of Conneaut Lake, large amounts of sand and gravel were deposited as the glacier receded. These deposits are now mined and stored upgradient of the lake. This has allowed for sediments and gravel to travel via stormwater runoff downgradient, which is leading to increased sediment and phosphorus loading to the lake.

Recommendations: Locate an area downgradient of the mining area (Figure 4.10) for a retention or collection basin that could reduce the amount of sedimentation from the stored sand/gravel.

A retention or collection basin will help reduce sediment and nutrient loads that could reach the lake. Stormwater runoff from the storage areas would collect in the basin, allowing for settling, infiltration and uptake of nutrients by plants. Depending on the site and type of basin used to intercept the site runoff, removal rates vary. At a minimum, TP will be reduced by 51.9 lbs/year, TSS by 48,713 lbs/yr, and TN will be reduced by 650 lbs/year. This basin could help diminish the effects of a major source of sediments and nutrients to the lake. Furthermore, retention and possibly infiltration in the basin would help to reduce hydrologic loading to the lake, contributing toward reducing the magnitude of flooding from this area.

Figure 4.10: Site conditions at Conneaut Lake Gravel Mine

The implementation of stormwater upgrades for site 6 would include Sadsbury Township with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

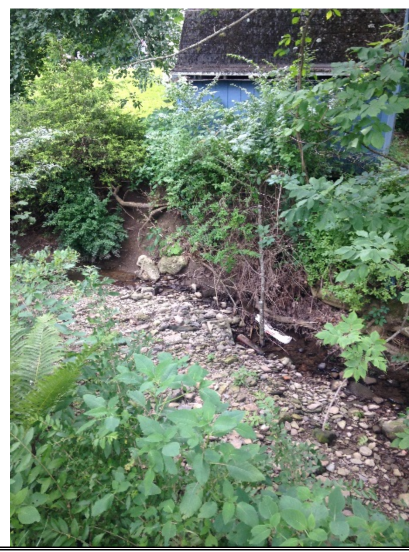
4.2.6 Site 7 – Midway Stream – Subwatershed 9

There is a large section of stream along the eastern side of Conneaut Lake. This stream runs through the lake community by Midway Beach (Figure 4.11). This stream weaves around many of the houses in this area and, in some sections, is constrained by concrete walls. The streambank is heavily eroding in various areas with some areas of erosion encroaching extremely close to properties. Stormwater throughout the community is routed directly to the confined stream channel. With the confinement of the stream and input of stormwater, flooding is a major issue within the community.

Recommendations: Restore the streambanks along reaches that have enough space through re-grading, floodplain reconnection and armoring with natural stone and woody materials. A coordinated community effort, rather than the current piecemeal stabilization is strongly recommended for the stream corridor. Currently, spatial requirements for floodplain reconnection are sparse but there is a portion of open land west of Route 18 between this street and the terminus of Willow Run Road. Homeowners should also be encouraged to implement vegetated riparian buffers on their properties where feasible and to implement small-scale rain gardens on their property to capture and retain stormwater to lessen the hydrologic load of this waterway. Installation of rain barrels should also be encouraged. Creating larger scale riparian areas is limited primarily to the upper reaches of the tributary, east of Route 18. The landowner immediately east of Route 18 may be willing to allow the retrofit of an existing pond for stormwater retention. A thorough review of this potential is recommended. The recommendations above will likely not solve flooding problems encountered by the homeowners along the stream corridor. SadsburyTownship may find that a buyout program for landowners adjacent to the stream channel would be the only effective option. The removal of existing structures and proper stream restoration and re-establishment of a functioning floodplain would help to solve some of the flood damage experienced within the community.

By restoring the banks of this stream, large amounts of excess sediment and nutrients derived from bank scour will be prevented from entering the lake. This is a large stretch of stream that weaves around the properties in this area. If the streambanks of the entire reach within the neighborhood were restored, nutrient loads could be reduced by 9.1 lbs TP/year, 6,670 lbs TSS/yr, and 52 lbs TN/year.

Figure 4.11: Midway Stream



The implementation of stormwater upgrades for site 7 would include Sadsbury Township with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

4.3 Summit Township

4.3.1 Site 8 – Lauderdale Estates – Subwatershed

The Lauderdale Estates community is located at the north end of the lake adjacent to the canal. The site is on Port Avenue and Thomas Drive. A stream runs through this neighborhood leading to the Conneaut Lake canal (Figure 4.12). This area was once a wetland area and the stream had been rerouted for residential housing. This stream runs behind the homes of Thomas Drive and down the side of Port Avenue. The stream has eroded banks throughout and in many places armoring was conducted through the placement of concrete slabs. On the residential side, a mostly unvegetated berm of dirt and gravel was installed to help prevent flooding. The section along Port Avenue has some erosion and undercut banks, with a few exposed tree roots. Mowed swales run alongside the majority of roads in this area. The canal in this area has high sediment buildup and nutrient issues.

Recommendations: Re-grade the stream bank and re-plant vegetation along the banks. Redo/grade sections along Port avenue and add a vegetated buffer. There are various roadside swales in the vicinity that could be vegetated or converted into step-pool type systems. Restoration should seek to maintain boat access as is currently in practice at the canal.

Restoring the streambanks of the reach of stream will decrease sediments and nutrients from the banks from accumulating in the canal. Through the restoration of the reach of stream from Lexington avenue to East Canal boulevard and retrofitting various swales in the neighborhood, a reduction of 3.5 lbs of TP, 2,802 lbs of TSS, and 18 lbs of TN per year may be realized.

Figure 4.12: Bank conditions at Lauderdale Estates



The implementation of stormwater upgrades for site 8 would include Summit Township (Lead) with assistance from Conneaut Lake Aquatic Management Association, Crawford County Conservation District and Crawford County Planning Commission. PA DEP Growing Greener or EPA 319 funds would be a good fit for these proposed projects.

4.3.2 Site 9 – Pa Fish and Boat Commission Boat Launch and Canal Outlet – Subwatershed 3

The Pennsylvania Fish and Boat Commission boat ramp is located along the northwestern shoreline off of George Street. The launch consists of a small paved parking lot and some mowed grassy areas. There is a small depression between the parking lot and the boat ramp. The area is located next to Inlet Run, which has a bulkhead along its edge. Erosion can be seen at the bulkhead from the pipe that leads from the depression. The northern end of the lake has high sediment buildup along the shoreline.

Recommendations: A rain garden/bioretention basin could be installed in the area between the parking lot and the ramp. Another recommendation would be to remove the bulk head and regrade the banks and create a living shoreline or re-plant the area to allow for some interception of nutrients.

Implementing a rain garden/bioretention system will help treat the stormwater runoff by filtering through the underlying soil and native vegetation. This BMP will help reduce TP loads by 6.5 lbs/year. It will also help reduce TSS and TN loads to 5,324 and 23 lbs/year, respectively. Since there are fewer BMP opportunities located near the northern end of the lake, this reduction in nutrients and sediments is highly recommended.

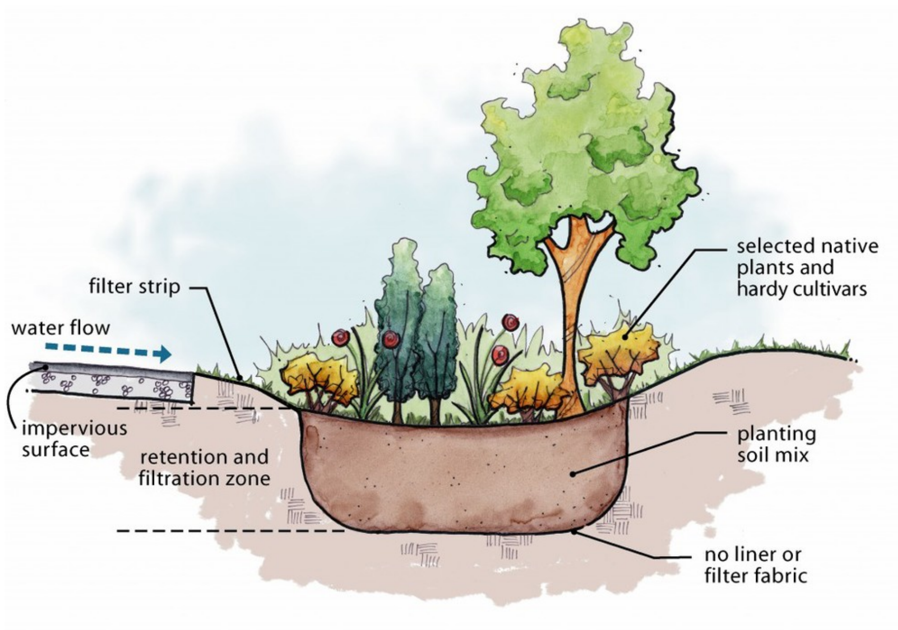
A main inlet to the lake is located directly adjacent to the boat launch. The exposed area of the inlet contains a bulkhead along the boat launch shore. This area also has no riparian buffer adjacent to the boat ramp, except for a small grassy strip. If the bulkhead is removed, the banks restored and replaced with a living shoreline or buffer, nutrient reductions would be 1.4 lbs TP/year, 1,035 lbs TSS/year, and 8 lbs TN/year.

If both BMPs were implemented in concert, the following nutrient reductions could be realized: TP 7.9 lbs/yr, TSS 6,359 lbs/yr, and TN 31 lbs/yr.

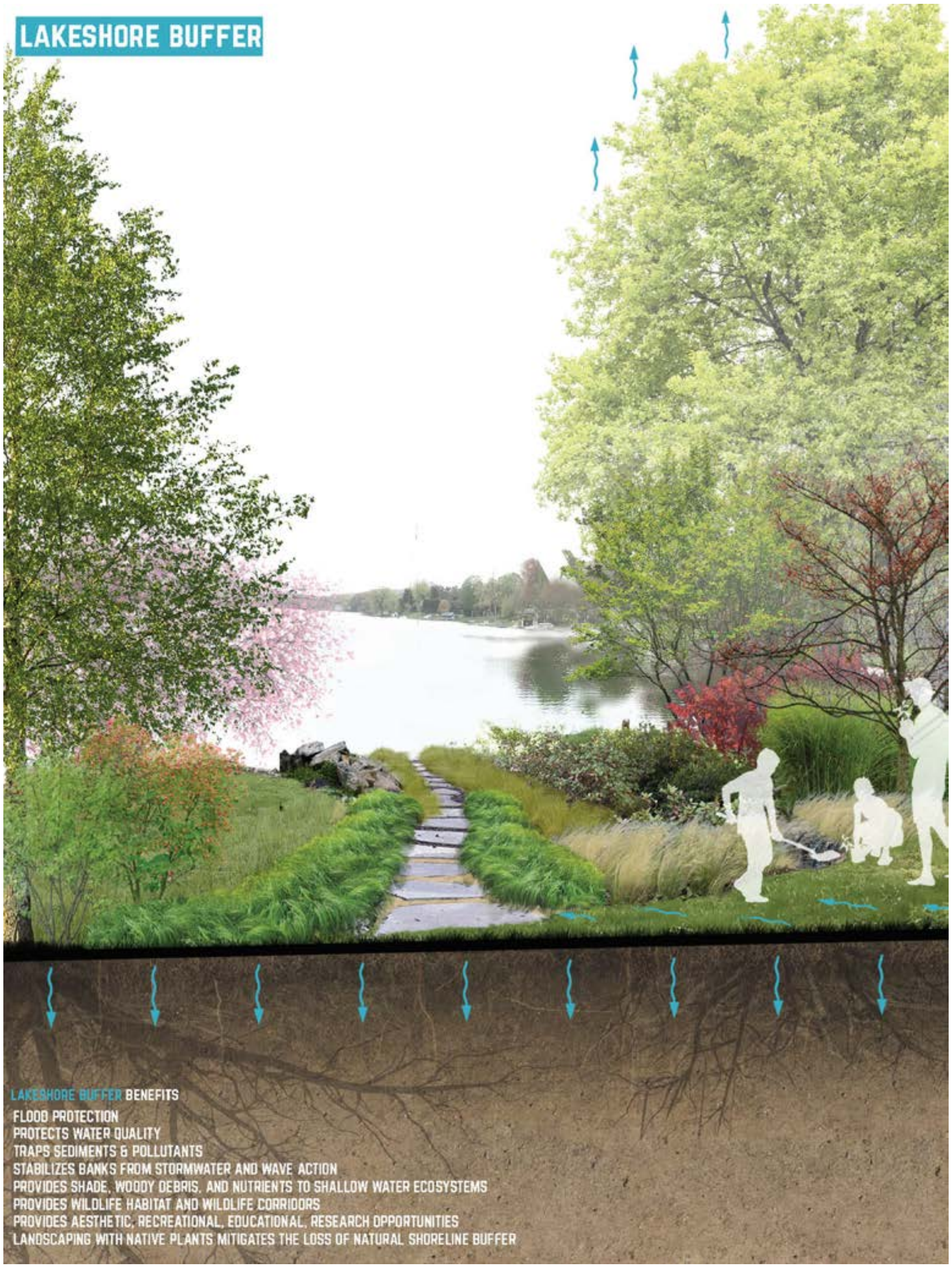
Figure 4.13 provides pictures of current site conditions while Figure 4.14 provides an illustrated example of a rain garden and Figure 4.15 provides an example of a vegetated lake shoreline.

Figures 4.13: Site conditions at the PAFBC boat ramp

Figures 4.14: Rain Garden Example



Figures 4.15: Lakeshore Buffer Example



Source: Mr. Josue Cruz / Syracuse University

Implementation of the selected BMPs at site 9 would likely include a partnership between the Crawford County Conservation District, Pennsylvania Fish & Boat Commission and Conneaut Lake

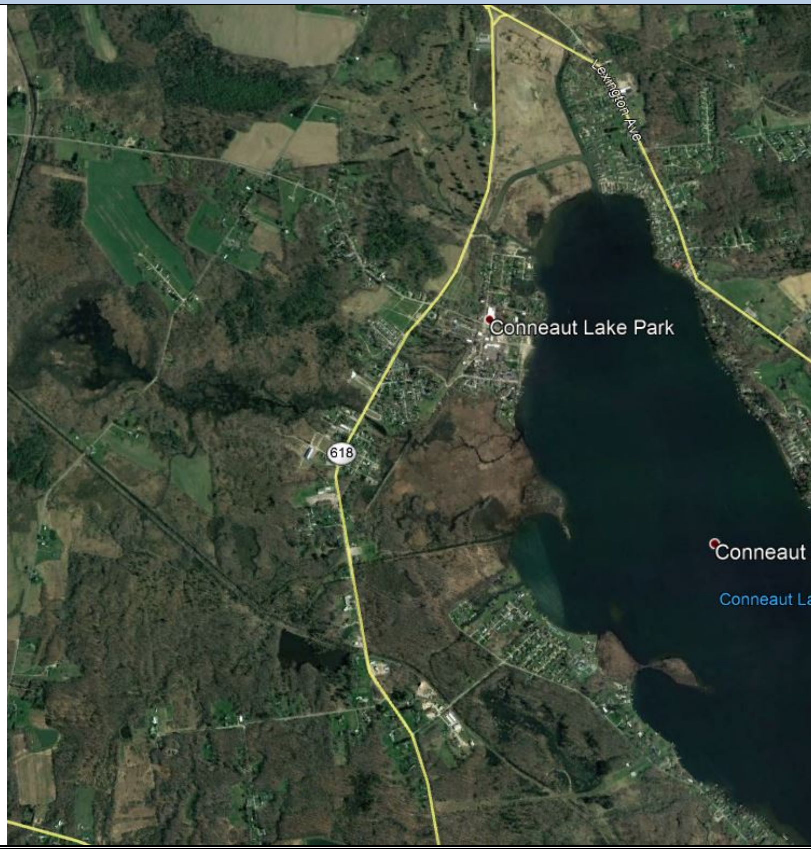
Aquatic Management Association with potential funding through PA Growing Greener or EPA 319.

4.4 Land Conservation

4.4.1 Site 10 – Potential Wetland Conservation Areas – Sub-watersheds 4 & 5

On the north and west side of Conneaut Lake are a number of large wetland complexes that have been modified and channelized over time, thus reducing their nutrient and sediment removal capacity. Many are identified as being subdivided by land holding companies. As a designated High Quality Warm Water Fishery the wetland complexes within this area are unlikely to be eligible for development. The municipalities have indicated that many of these proposed developments are purchased by developers unaware of the HQ-WWF designation and existence of wetlands, to be met with permitting hurdles only to be denied permits. The sites are then turned around and sold again only to repeat the process. A conservation easement and/or restoration of these areas would be a more practical use of the land and help to improve the water quality of Conneaut Lake. These wetland complexes are mainly located on the northern and eastern sides end Conneaut Lake (Figure 4.16), but exist throughout the watershed. Restoring streams through the wetland proper, increasing floodplain connection and restoring the natural function of these wetlands could help to significantly reduce nutrient loading from sub-watershed 4 and also serve to attenuate, to some degree, flooding.

Figure 4.16: North End Wetland Complex



Recommendations: Encourage local land conservancies to work directly with each municipality to prioritize and pursue these wetland complex lands as they become available. Where appropriate, it may be possible to design /construct a large wetland treatment complex. Design the wetland treatment system in such a manner as to allow stormwater to be diverted into created floodplain cells for evapotranspiration and infiltration of water, settling of solids and the assimilation of nutrients.

Such a large-scale, enhanced wetland BMP has the potential to remove 151 lbs of TP per year, 103,666 lbs of TSS per year and 942 lbs of TN per year.

The various entities responsible for pursuing conservation easements would include various local land conservation organizations such as French Creek Valley Conservancy, Western Pennsylvania Conservancy, Ducks Unlimited, as well as others with assistance from Conneaut Lake Aquatic Management Association.

4.5 Street Sweeping

Street sweeping has proven a viable method for removing accumulations of sediment and associated nutrients on the impervious areas throughout the watershed and should be continued. Pollutant removal estimates on an annual basis for the Conneaut Lake watershed are 2 lbs TP, 600 lbs TSS, and 5 lbs TN.

4.6 Individual Homeowner Actions

4.6.1 Lawn Fertilizers

Lawn fertilizers are often an acute source of nutrient pollution to lakes. Often, these products are applied in spring or fall and are quickly washed away during precipitation events directly into the lake where they fuel algal blooms. Prior to application of any fertilizers, homeowners should have their soil tested by the local extension office or similar entity. This testing will provide empirical data on the amount of nutrients in the soil and need for any additional nutrients. Often times, phosphorus is present in abundance in soils and does not need additional application. Many times, the pH of the soil needs adjusted with lime thereby raising pH to a level where the phosphorus that is present in the soil becomes biologically available for turf grass. If fertilizers are needed, homeowners should look for and use phosphorus free fertilizers. Fertilizers are typically labeled with three vales (N-P-K) representing the proportion of nitrogen – phosphorus – potassium in the product. As such, look for fertilizers with a middle number of zero (e.g. 24-0-12) or a bag with 'lake friendly' on the front.

4.6.2 Rain Barrels

There are extensive areas of impervious cover throughout the immediate lake area which result in increased volumes of stormwater reaching the tributaries and lake during storm events. This increase in volume serves to degrade tributaries through increased scour and erosion leading to heavy sediment and phosphorus loads to the lake. In addition, there is little room immediately surrounding the lake for the installation of large-scale BMPs. As such, it is increasingly important for each homeowner to limit their impact on NPS loading. One of the ways individual homeowners can work to reduce the volume of stormwater to the lake is by installing rain barrels on each downspout. Rain barrels are essentially small-scale cisterns which intercept roof runoff and store this water to be drained slowly or used for watering / gardening around the yard.

4.6.3 Small-scale Rain Gardens

Where space permits, each homeowner should attempt to integrate small-scale rain gardens on their property. Rain gardens are simply small depressions planted with water loving vegetation that serve to intercept runoff from the surrounding areas (i.e. roofs, driveways, turf areas etc.). This runoff is slowed and will infiltrate into the ground or evapotranspire through vegetation. Furthermore, these small gardens are excellent at settling solids and removing phosphorus and nitrogen before it enters the lake.

4.7 Floating Wetland Islands

Floating Wetland Islands (FWIs) are an aesthetically pleasing, ecologically friendly means of reducing in-lake nutrient concentrations originating from NPS pollution. The islands are composed of a recycled plastic material that is planted with native vegetation. The plants and associated microbial community (called a biofilm) that develops on their roots and within the island matrix, contribute toward nutrient uptake. It should be noted that it is this biofilm of microbes that greatly increases the levels of nutrient uptake associated with the FWIs.

The matrix material of the FWI has a tremendous amount of surface area and it is estimated that one (1), 250 square foot floating island is roughly equivalent to one (1) acre of wetland in terms of surface area and nutrient uptake. Additionally, third party field studies have estimated that one 250 sq. ft. FWI can remove 10 lbs of phosphorus from the water column per year. One pound of phosphorus has the potential to generate up to 1,100 lbs of wet algae biomass. Therefore, one 250 sq. ft. FWI has the potential to prevent the growth of up to 11,000 lbs of algae.

Installing various FWI's in more problematic areas of the lake will help reduce the nutrient loads to the lake. Areas that would benefit most are shallow areas with inlets or stormwater inputs such as near the northern end to intercept stormwater from sub-watersheds 3, 4 and 5.

Recommendation: Install one 250 sq. ft. FWI at a nearshore area, adjacent to a stormwater pipe in each of the three sub-watersheds cited above, which would remove 30 lbs of TP per year.

5.0 In-Lake Restoration Measures

5.1 Harvesting

Harvesting has been routinely conducted in Conneaut Lake to reduce nuisance levels of macrophytes. The added benefit of this in-lake management measures is that the nutrients that are contained within macrophyte biomass are effectively removed from the system.

The program has had varying degrees of success depending on operation schedules, ranging from harvest yields of 40 tons/year to 700 tons/year, with an inter-annual mean of approximately 400 tons/year. Plant / Mussel biomass collected by Princeton Hydro was collected during the 2016 macrophyte survey (Section 9), subsequently forwarded to a laboratory for analysis and produced mean concentrations of 0.001083 lbs/lb (1,083 mg/kg) of TP and 0.0124 lbs/lb (12,400 mg/kg) of TN. Phosphorus removals calculated by Princeton Hydro ranged from a minimum of 7 lbs/year to 121 lbs/year with a mean of 69 lbs/year. Nitrogen removals calculated by Princeton Hydro ranged from 79 lbs/year to 1,389 lbs/yr with a mean of 792 lbs/year. Therefore, these removals account for approximately .2% to 4% of the annual internal P load with a mean annual removal of 2.3% of the annual internal P load. As such, the harvesting effort has the potential to remove a portion of the P regenerated from internal sources and should be continued.

5.2 Nutrient Inactivation

Nutrient inactivation, while not a watershed-based management practice, may be extremely effective at mitigating the substantial internal phosphorus loading occurring in the lake. In fact, approximately 85% of the annual reduction target could be met by mitigating the internal release of phosphorus from the sediments. One of the potential draw-backs to this approach is that regulatory agencies that issue funding are typically heavily weighted to apply funds to watershed-based projects *before* funding for in-lake nutrient inactivation. If some progress was made in implementing several of the aforementioned watershed BMPs then regulatory agencies may be more likely to issue grant funds for internal nutrient control. A similar circumstance of watershed and internal load control took place at Stephen Foster Lake in Bradford County, Pennsylvania. An alum treatment was funded through grant sources and conducted but only after significant progress in the watershed was made.

Using alum or an alum surrogate (e.g. Polyaluminum chloride) to create a "blanket" over the sediments would be the recommended management action that would reduce the largest source of phosphorus for Conneaut Lake. The aluminum would bind with phosphorus as it leached out of the sediments under anoxic conditions (DO < 1 mg/L), making it unavailable for algal growth.

The first step in conducting such a treatment would be conducting a series of bench tests which would be utilized to determine which alum product could be utilized. Essentially, various alum products would be titrated in lake water samples to see if the effective dose can be applied without reducing the lake pH to a level at which aluminum would become dissolved and toxic to aquatic life (pH of approximately 6.2). If standard alum could not be utilized then a buffering agent may need to be added or a different product evaluated. The actual alum treatment would be conducted with a barge that would meter the alum out over the deep portions of the lake which become anoxic and release internal P. If there is no updated bathymetric map (i.e. within the past 5-10 years) then an updated bathymetry should be conducted in order to compute the proper dose and apply the product in the proper locations. Typically, an alum treatment will provide 5 – 7 years of control of internal P release.

A tentative, ball-park estimated combined cost for a bench test, bathymetric survey and alum treatment for Conneaut lake would be approximately $200,000 - $300,000. A more refined cost could be computed after conducting the bench test which would inform the product most suitable for Conneaut Lake.

6.0 BMP Type and Pollutant Reduction Summary

The following Table (6.1) provides a summary of the watershed and in-lake BMP recommendations listed in sections 4 and 5. This table lists the type of BMP recommended and estimated pollutant removal for TP, TN and TSS. Cost estimates and maintenance requirements for the recommended BMPs are listed in section 7 below. The next table (6.2) summarizes only the watershed based BMPs, their phosphorus reduction, and this amount relative to the reduction needed to satisfy the watershed portion of the P load reduction needed to meet the TMDL (479 lbs of P/year).

Table 6.1: Recommended BMP Summary – Watershed & In-lake

Site	BMP Types	Pollutants Removed (lbs/yr)		
		TN	TP	TSS
1 – Maintenance Lot	Bioswale & 3-Chambered BB	121	28.7	19,252
2 – Conneaut Boat Launch	Rain garden & Living shoreline	31	7.9	6,359
3 - Iroquois Road	Bioswales & 3-Chambered BB	11	2.8	3,929
4 - Konneyaut Trail	Step-pool conveyance	4	1.2	1,119
5 - Seneca Road	Basin retrofit, Step-pool conveyance and 3-Chambered BB.	15	3.1	3,665
6 – Foust Road	Step-pool conveyance or Bioswale and 3-Chambered BB.	87	9.3	11,875
7 - Mine	Biofiltration basin	650	51.9	48,713
8 - Midway Stream	Floodplain connection, Riparian buffers, & streambank armoring	52	9.1	6,670
9 - Lauderdale Estates	Stream restoration & Step-pool conveyance	18	3.5	2,802
10 – Lauderdale Wetland	Wetland Restoration	942	151	103,666
11 – Snow Waters Golf Course	Conservation			
12 – Street Sweeping		5	2	600
13 – Floating Wetland Islands	Floating Wetland Islands (250 sq. ft.) – three units		30	
14 – In-lake	Harvesting		69 (Average)	
15 – In-lake	Nutrient Inactivation		2,713	

Table 6.2: Watershed BMPs as function of watershed based TMDL		
Site	Mass of TP Removed (lbs/yr)	% of TMDL (**watershed)**
1 – Maintenance Lot	28.7	6%
2 – Conneaut Boat Launch	7.9	1.7%
3 - Iroquois Road	2.8	0.6%
4 - Konneyaut Trail	1.2	0.3%
5 - Seneca Road	3.1	0.7%
6 – Foust Road	9.3	1.9%
7 - Mine	51.9	10.8%
8 - Midway Stream	9.1	1.9%
9 - Lauderdale Estates	3.5	0.7%
10 – Lauderdale Wetland	151	31.5%
11 – Snow Waters Golf Course	Conservation	
12 – Street Sweeping	2	0.4%
13 – Floating Wetland Islands (3)	30	6.3%
14 - Historic Watershed BMPs	26.8	5.6%
Sum	327.3	68.3%

As shown in Table 6.2, implementation of all recommended watershed BMPs in addition to the historical watershed BMPs is estimated to remove approximately 327.3 lbs/TP/yr. This load accounts for approximately 68.3% of the load reduction necessary for watershed-based sources per the TMDL.

As previously cited, the targeted watershed-based reduction in TP for Conneaut Lake is 479 lbs per year. Thus, the projects listed above would account for approximately 68.3% of this external load. It is recommended that work on securing funds and the subsequent design / implementation of these projects be initiated in 2019-2020. After between five and ten years the WIP should then be re-assessed and updated. The purchase of additional lands, the implementation of other land-use conservation practices, the development of new technologies may require and changes in regulations / sources of funding, may result in the need for significant changes to the WIP. Additionally, after a set of these watershed-based projects have been implemented and the WIP is re-assessed, it is recommended that the internal TP load be considered for control.

In order to result in complete compliance with the TMDL, which would mean a total (external and internal) reduction of 3,192 lbs in TP, it is recommended that sometime in the future the internal phosphorus load will need to be addressed. The utilization of aeration to keep the lake de-stratified and well mixed to prevent the depletion of dissolved oxygen (DO) over the sediments, can be an effective means of controlling the internal phosphorus load. However, given the size of the lake, the needed infrastructure, maintenance and energy costs, nutrient inactivation is tentatively recommended over destratification through aeration.

Using alum or an alum surrogate to create a “blanket” over the sediments would be the recommended management action that would reduce the largest source of phosphorus for Conneaut Lake. The aluminum would bind with phosphorus as it leached out of the sediments under anoxic conditions (DO < 1 mg/L), making it unavailable for algal growth. While such a project would reduce the largest source of phosphorus, it is strongly recommended that this management technique be scheduled sometime after a number of the watershed-based management projects are completed. Conducting nutrient inactivation would do nothing to reduce the watershed-based TP load, as well as other pollutants such as TSS. In addition, nutrient inactivation would not contribute toward reducing the magnitude and frequency of localized flooding. Thus, it is strongly recommended that a portion of the watershed-based projects be completed before nutrient inactivation is considered. Details on the proposed schedule is provided in Section 9.0.

7.0 Technical and Financial Assistance Needed to Implement BMPs

Estimated costs for the installation and maintenance of each proposed stormwater structure are provided below in Table 7.1. Total costs will range depending on the ultimate design and number of projects addressed at each site. A high and low estimate are provided for a general range of potential implementation and maintenance costs.

Table 7.1: Estimated Costs for Project Implementation and Maintenance at Conneaut Lake

Site Location	Implementation		Maintenance	
	LOW	**HIGH**	**LOW**	**HIGH**
1 - Maintenance Parking Lot	$150,000	$250,000	$2,500	$3,500
2 - Conneaut Boat Launch	$30,000	$60,000	$500	$3,000
3 - Iroquois Road	$250,000	$400,000	$500	$2,500
4 - Konneyaut Trail	$40,000	$200,000	$750	$2,000
5 - Seneca Road	$400,000	$950,000	$2,000	$5,000
6 - Foust	$150,000	$250,000	$500	$1,500
7 - Mine	$200,000	$300,000	$2,000	$5,000
8 - Midway Stream	$200,000	$600,000	$2,000	$10,000
9 - Lauderdale Estates	$100,000	$300,000	$2,000	$10,000
10 – Lauderdale Wetland	$1,000,000	$2,000,000	$10,000	$25,000
13 – Wetland Easements and Restoration	Conservation			
14 – Street Sweeping	On-Going			
15 – Floating Wetland Islands	$45,000	$60,000	$1,000	$2,000
Total	**$2,565,000**	**$5,370,000**	**$23,750**	**$69,500**

Financial assistance for the projects summarized in Table 7.1 should be pursued through grant funding. The Pennsylvania Growing Greener grant program and funding through the United States Environmental Protection Agency 319 non-point source pollution grant should be the two primary funding mechanisms to implement these watershed-based projects. The most recent funding amounts through PA Growing Greener (2016 funding year) was $20.7 million while the most recent funding through 319 (2017 fiscal year) was $167.9 million. Municipalities (Borough of Conneaut Lake and townships), conservation districts, land conservancies and registered non-profits are eligible for grant funding through these programs.

Additional grant funding may be available from private, non-profit institutions or through other governmental agencies such as the National Fish and Wildlife Foundation (NFWF), United States Fish and Wildlife Service (USFWS), Foundation for Pennsylvania Watersheds and the Heinze Endowments may also serve as funding vehicles for sustainable stormwater projects.

8.0 Education and Outreach

Education and outreach is an important aspect of watershed management. While large scale projects are done and overseen by the Conneaut Lake Aquatic Management Association and funded by various grants or programs, small scale changes can be done by residents for no cost. By informing residents of various improvements they can make, such as forgoing or altering their lawn fertilizing practices, keeping yard waste from entering the lake and streams, excess nutrients will be prevented from entering the ecosystem. The Conneaut Lake Aquatic Management Association (CLAMA) should continue the dissemination of information on what small changes in behavior and land-use practices can mean on lower phosphorus loading to the lake. Some of these measures were already discussed in Section 4.6.

Routine public meetings associated with the development of this WIP and following its completion have been held and should continue to be held. Indeed, meetings were held between the Conservation District, CLAMA and Princeton Hydro during the development of this WIP as stakeholder input is critical in development of a suitable plan. Furthermore, these meetings should be continued to gather support for the implementation of the BMPs discussed as part of this WIP.

Increasing support through press releases to local media outlets should also be conducted to continue education for those aware of lake issues and to bring new stakeholders into the discussion of watershed and lake restoration and management.

A potential source of funding or outreach and education at Conneaut Lake would be The Consortium for Scientific Assistance to Watersheds (C-SAW) program through the Pennsylvania Lake Management Society. C-SAW can provide funds for outreach that teaches stakeholders about proper water quality management. Examples of projects could include workshops on basic lake ecology, or best management practices. C-SAW can also be used to train local community members how to conduct water quality monitoring programs. It is recommended that CLAMA pursue funds like C-SAW to further this effort.

9.0 Implementation Schedule & Milestones

Implementation of the recommended BMPs will be highly dependent on available funding sources and technical logistics for each recommended watershed measure. The milestones set for the watershed will be the completion of each recommended BMP with the completion of all recommended projects within a ten (10) to fifteen (15) year timeframe. Logistical, budgetary or unforeseen issues may arise for each BMP which may render them unable to be installed. In that case, substitute projects should be identified. These changes will necessitate periodic updating of the WIP with modifications completed approximately once every five (5) years. A tentative implementation schedule for each of the specific BMPs is listed in Table 9.1.

Table 9.1: Implementation Schedule

Site & Recommendations	**Estimated Completion Dates**
1 – Maintenance Lot – Baffle box, bioswale	2021
2 – Boat Launch – Rain Garden / Living Shoreline	2021
3 – Iroquois Road – Bioswale / Step-pool / Baffle Boxes	2024
4 – Konneyaut Trail – Bioswales / Step-pool	2024
5 – Seneca Road – Basin Retrofit / Bioswales or Step-pool / Baffle Box	2024
6 – Foust Road – Baffle Box	2024
7 – Gravel Mine – Retention Basin	2028
8 – Midway Stream – Stream Restoration	2028
9 – Lauderdale Estates – Stream Restoration	2033
10 – Wetland Restoration	2033
11 – Wetland and open space easements – Conservation	2033
13 – Floating Wetland Islands	2021

Once a set of the watershed-based projects have been completed, nutrient inactivation should then be seriously considered for implementation. Tentatively, nutrient inactivation should be considered after at least a few of the watershed projects are completed (approximately 3-5 years after the initiation of the WIP). A similar model was used for Lake Carey, located in Wyoming County, PA. For Lake Carey, its WIP was approved in 2008 and a series of stormwater BMPs, MTDs and Floating Wetland Islands were designed and installed between 2009 and 2016 using funds from the Growing Greener grant program. Additionally, in 2016 an application was submitted to conduct a nutrient inactivation in the deepest section of the lake. This application was awarded funding and the nutrient inactivation treatment will be conducted in 2018 or 2019, approximately 10 years after the WIP was initially approved. A similar model is recommended for Conneaut Lake.

Finally, it should again be emphasized that the WIP is a flexible, living document that can be easily modified as a result of site-specific conditions, land availability / limitation and funding opportunities. For example, the availability of some previously unidentified vacant land that could be purchased and converted into some large-scale, wetland BMP complex, should be considered if such a situation arises. Periodic, 5-year updates on the WIP will also provide a means of ensuring the plan is up to date relative to existing technology, regulations and sources of funding.

10.0 Evaluation and Monitoring

With the implementation of any watershed-based project, a series of stormwater monitoring events should be conducted under pre- and post-installation conditions, with the post-installation conditions collecting samples as stormwater flows into and out of each BMP. Some of the larger BMPs may require multiple years of monitoring for an inter-annual estimate of their pollutant removal rates. Such site-specific stormwater data, coupled with some simplified pollutant loading modeling, can provide a means of quantifying the pollutant loading capacity of each BMP or project.

In-lake and stream monitoring should be conducted to gauge how Conneaut Lake is responding to the reductions in the pollutant loads. This will build upon the inter-annual database to identify long-term changes or trends in water quality. Routine observations on the extent of macrophyte growth in the lake and water clarity as measured with a Secchi depth would also provide valuable information on the ongoing issues within the lake. Other *in-situ* monitoring parameters, such as temperature and dissolved oxygen profiles, pH and conductivity, will provide insight into the health of the waterbody as the WIP is being implemented. Additionally, multiple years of *in-situ* data will be useful to quantify the magnitude of the internal load in eventually calculating the required dosage rate for nutrient inactivation.

Additional discrete parameters should be collected to determine the effect on nutrient and sediment loads within the waterbody. Total phosphorus, nitrates, ammonia and total suspended solids should be monitored in order to assess reductions in nutrient levels. Chlorophyll *a* should also be monitored to measure algal productivity. Phytoplankton and zooplankton samples should also be collected to determine the algal community present. Additionally, some selective, nearshore sampling at the beach areas should be collected in summer and early fall for the analysis of microcystins, one of the most common cyanotoxins

After post-installation monitoring is completed, the stormwater data should be utilized to calculate the pollutant removal efficiency of the installed BMPs. These data would be subsequently utilized for the submission of progress reports which outlines the progress made towards attaining the targeted phosphorus load outlined in the TMDL.

As described in Section 8.0, funds are available through the C-SAW program to educate stakeholders on water quality monitoring methods. It is recommended that in addition to monitoring by agency and academics, CLAMA should pursue community members that would be able to conduct simple monitoring such as a weed warrior program, Secchi depth or possibly some *in situ* monitoring. A local school environmental club, or a lake resident that spends a lot of time on the lake may be a good choice.

11.0 Updated Macrophyte Survey

Princeton Hydro conducted a detailed macrophyte survey of Conneaut Lake as part of this WIP. This survey aimed to document the densities and distributions of invasive and native macrophytes in the lake. Furthermore, this survey aimed to document the presence, density and distribution of zebra mussels throughout the lake.

11.1 Methodology

The macrophyte survey of Conneaut Lake was conducted on 18 July 2016. Monitoring of the survey transects was conducted by Princeton Hydro staff trained in aquatic plant identification and survey methods. A line intercept sampling methodology (Madsen 1999) was used to sample all transects. At each site, Princeton Hydro established a 100-foot transect which extended from the shoreline out into the center of the lake. In total, twelve (12) transects were monitored. Along each transect, transect plots were sampled at approximately 20, 40, 60, 80 and 100 feet from the shoreline. Each plot was delineated by using a floating $1m^2$ quadrat. The area inside the quadrat, outlined on the lake bottom by drop chains, was observed and sampled using an Aquascope® or mask and snorkel. The plant community was identified to the lowest practical taxon (generally species) and ranked according to abundance using the following criteria: (A) **Abundant**, greater than or equal to 50% of quadrat area, (C) **Common,** 10% to 50% of quadrat area, (P) **Present,** less than or equal to 10% of quadrat area. Along each transect Princeton Hydro harvested all above ground plant biomass within a square meter. The resultant biomass was measured as wet weight to the nearest gram. In addition, Princeton Hydro noted the presence/absence and relative densities of zebra mussels at each transect. Zebra mussels were included in biomass measurements. Species identifications were made utilizing previous identification knowledge and various aquatic plant field guides including Borman (1997) and Hellquist (1980).

11.2 Results

Twenty (20) macrophytes and one (1) macroalgae were identified by Princeton Hydro and the Crawford County Conservation District over the one-day study conducted on 18 July 2016. A taxonomic list of all species identified during the study is presented in Table 11.1.

Table 11.1: Conneaut Lake – SAV Survey – Taxonomic List	
Common Name	**Scientific Name**
Richardson's Pondweed	*Potamogeton richardsonii*
Flat-Stem Pondweed	*Potamogeton zosteriformis*
Largeleaf Pondweed	*Potamogeton amplifolius*
Fern-Leaf Pondweed	*Potamogeton robbinsii*
Thin-Leaf Pondweed	*Potamogeton pusillus*
Curly-Leaf Pondweed	*Potamogeton crispus*
Sago Pondweed	*Stuckenia pectinata*
Coontail	*Ceratophyllum demersum*
Vallisneria	*Vallisneria americana*
Elodea	*Elodea canadensis*
Slender Naiad	*Najas flexilis*
Southern Naiad	*Najas guadalupensis*
Brittle Naiad	*Najas minor*
Fanwort	*Cabomba caroliniana*
Water Moss	*Fontinalis sp.*
Water Stargrass	*Heteranthera dubia*
Yellow Pond-Lily	*Nuphar variegata*
White Waterlily	*Nymphaea odorata*
Marsh marigold	*Megalondonta beckii*
Eurasian Watermilfoil	*Myriophyllum spicatum*
Chara	*Chara* sp.

Community analysis of each transect is presented in Tables 11.2 through 11.14.

Table 11.2: Conneaut Lake – SAV Survey – Transect 1						
Conneaut Lake - T1 - 7/18/16						
Common	Species	20	40	60*	80	100
Richardson's Pondweed	*Potamogeton richardsonii*		P	C	C	P
Coontail	*Ceratophyllum demersum*			P	P	P
Vallisneria	*Vallisneria americana*			C	A	A
Elodea	*Elodea canadensis*				P	P
Slender Naiad	*Najas flexilis*			P	P	C
Sago Pondweed	*Stuckenia pectinata*		P			
Water Moss	*Fontinalis sp.*	P				
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 1 was located in the northeast portion of the lake. Species richness was moderate with seven species identified. No invasive macrophytes were identified and densities increased with distance from shore where *Vallisneria* was most abundant. Biomass measures at 60' were the lowest of all transects with a measure of 265 g/m^2. Zebra mussels were identified at this station amongst SAV.

Table 11.3: Conneaut Lake – SAV Survey – Transect 2						
Conneaut Lake - T2 - 7/18/16						
Common	Species	20	40	60	80*	100
Vallisneria	*Vallisneria americana*		C	A	P	A
Water Moss	*Fontinalis* sp.	A	A	A	A	A
Coontail	*Ceratophyllum demersum*					P
Fanwort	*Cabomba caroliniana*		P	P	P	
Water Stargrass	*Heteranthera dubia*				P	
Yellow Pond-Lily	*Nuphar variegata*		P		P	
Eurasian Watermilfoil	*Myriophyllum spicatum*		P		P	
Flat-Stem Pondweed	*Potamogeton zosteriformis*				P	
Richardson's Pondweed	*Potamogeton richardsonii*	C	P			
Slender Naiad	*Najas flexilis*	C				
Southern Naiad	*Najas guadalupensis*	C				
Zebra Mussel	*Dreissena polymorpha*	Present				

Located due south of T1, T2 showed high species richness with a total of eleven species identified including the invasive species fanwort and Eurasian watermilfoil. *Vallisneria* was the dominant plant in terms of biomass while the low-growing water moss was also abundant.

Biomass at T2 was moderate with a measure of 1,895 g/m^2. Zebra mussels were noted at T2.

Table 11.4: Conneaut Lake – SAV Survey – Transect 3

Conneaut Lake - T3 - 7/18/16						
Common	Species	20	40*	60	80	100
Slender Naiad	*Najas flexilis*	A	A	A	A	A
Elodea	*Elodea canadensis*		P			P
Flat-Stem Pondweed	*Potamogeton zosteriformis*				C	P
Vallisneria	*Vallisneria americana*					C
Yellow Pond-Lily	*Nuphar variegata*	A	A	A	A	A
Watershield	*Brasenia schreberi*		C		C	C
Coontail	*Ceratophyllum demersum*				P	P
Chara	*Chara* sp.				P	
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 3 was located along the western shoreline of the lake, south of T2. Species richness was moderate with seven macrophytes and one macroalgae. Yellow pond-lily was abundant throughout the station on the surface while slender naiad was abundant in the water column at all distances. Biomass measures at the 40' mark of T3 were relatively low with a measure of 500 g/m^2.

Table 11.5: Conneaut Lake – SAV Survey – Transect 4

Conneaut Lake - T4 - 7/18/16						
Common	Species	20	40	60	80*	100
Largeleaf Pondweed	*Potamogeton amplifolius*	C	A	A	A	A
Vallisneria	*Vallisneria americana*	A				
Slender Naiad	*Najas flexilis*	P		P	P	
Coontail	*Ceratophyllum demersum*	P	P	P	P	
Fanwort	*Cabomba caroliniana*		P		P	
Flat-Stem Pondweed	*Potamogeton zosteriformis*			P		
Richardson's Pondweed	*Potamogeton richardsonii*				C	
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 4, located along the western shoreline, south of T3, was characterized by moderate species richness with 7 species listed. Diversity was moderate at this station with relative abundance of all macrophytes similar with the exception of an abundance of largeleaf pondweed throughout. Macrophyte biomass at T4 was elevated with a measure of 2,094 g/m^2 and zebra mussels were identified at this station.

Table 11.6: Conneaut Lake – SAV Survey – Transect 5						
Conneaut Lake - T5 - 7/18/16						
Common	Species	20	40	60*	80	100
Flat-Stem Pondweed	*Potamogeton zosteriformis*	C	A	A	A	A
Fern-Leaf Pondweed	*Potamogeton robbinsii*					P
Largeleaf Pondweed	*Potamogeton amplifolius*	C		P		P
Thin-Leaf Pondweed	*Potamogeton pusillus*					C
Fanwort	*Cabomba caroliniana*			P		
Vallisneria	*Vallisneria americana*	A	A			
Zebra Mussel	*Dreissena polymorpha*	Not Present				

Transect 5, located along the western shoreline of the lake, south of T4 was comprised of 6 species. The most dominant species at this transect was flat-stem pondweed followed by *Vallisneria* and largeleaf pondweed. Macrophyte biomass was elevated with a measure of 6,084 g/m^2 and zebra mussels were not present at this station.

Table 11.7: Conneaut Lake – SAV Survey – Transect 6						
Conneaut Lake - T6 - 7/18/16						
Common	Species	20	40*	60	80	100
Slender Naiad	*Najas flexilis*	A	A	A	A	A
Vallisneria	*Vallisneria americana*	P	P	A	C	A
Richardson's Pondweed	*Potamogeton richardsonii*	C			C	
Coontail	*Ceratophyllum demersum*		P			
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 6 was located in the southwestern portion of the lake. Species richness was relatively low with four species identified, all of which were native. Slender naiad and *Vallisneria* were the dominant species. Total biomass at T6 was high with a measure of 8,130 g/m^2 and zebra mussels were identified at this station.

Table 11.8: Conneaut Lake – SAV Survey – Transect 7						
Conneaut Lake - T7 - 7/18/16						
Common	Species	20	40	60	80*	100
Slender Naiad	*Najas flexilis*		A	A	A	A
Vallisneria	*Vallisneria americana*	A	A	A	C	P
Coontail	*Ceratophyllum demersum*	P			P	
Richardson's Pondweed	*Potamogeton richardsonii*	C	C	C		
Fanwort	*Cabomba caroliniana*		P	P		
Elodea	*Elodea canadensis*	A				
Flat-Stem Pondweed	*Potamogeton zosteriformis*	C				
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 7 was located on the southwest shoreline of the lake and was immediately south of T6. Species richness at T7 was higher than that at T6 with seven species identified. Slender naiad and *Vallisneria* were abundant while Richardson's pondweed was also present in moderate densities. Total macrophyte biomass at T7 was high but lower than that measured at T6 with a measure of 4,599 g/m^2. Zebra mussels were identified at T7.

Table 11.9: Conneaut Lake – SAV Survey – Transect 8						
Conneaut Lake - T8 - 7/18/16						
Common	Species	20	40	60	80	100*
Chara	*Chara* sp.	P	C			C
Slender Naiad	*Najas flexilis*			C	A	P
Vallisneria	*Vallisneria americana*				C	
Largeleaf Pondweed	*Potamogeton amplifolius*		P	P	P	
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 8 was located along the southeast shoreline of the lake. Species richness was relatively low at this station with three macrophytes and one macroalgae identified, none of which were non-native. Slender naiad was the most abundant followed by *Chara* and *Vallisneria*. Macrophyte biomass was relatively low with a measure of 308 g/m^2 and zebra mussels were identified.

Table 11.10: Conneaut Lake – SAV Survey – Transect 9

Conneaut Lake - T9 - 7/18/16						
Common	Species	20	40	60	80*	100
Elodea	*Elodea canadensis*					P
Coontail	*Ceratophyllum demersum*	P			P	P
Vallisneria	*Vallisneria americana*	C	P	C	A	A
Slender Naiad	*Najas flexilis*	C	C	A	C	A
Richardson's Pondweed	*Potamogeton richardsonii*					P
Largeleaf Pondweed	*Potamogeton amplifolius*			P		
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 9 was centrally located along the east shore of Conneaut Lake. Species richness at T9 was moderate with six species identified. Dominance in the plant community was exerted between *Vallisneria* and slender naiad. Biomass at T9 was moderate with a measure of 728 g/m^2 and zebra mussels were identified.

Table 11.11: Conneaut Lake – SAV Survey – Transect 10

Conneaut Lake - T10 - 7/18/16						
Common	Species	20	40*	60	80	100
Vallisneria	*Vallisneria americana*		A	A	A	A
Largeleaf Pondweed	*Potamogeton amplifolius*					P
Coontail	*Ceratophyllum demersum*		P	P	P	C
Richardson's Pondweed	*Potamogeton richardsonii*	C	A	A		
Slender Naiad	*Najas flexilis*		P	C		
Chara	*Chara* sp.	C	P			
Zebra Mussel	*Dreissena polymorpha*	Present				

Transect 10 was located along the northeast shore of Conneaut Lake. Species richness was moderate with six species identified. *Vallisneria* was the most prevalent species followed by Richardson's pondweed and coontail. Biomass measures at T10 were similar to those measured at T9 with a measure of 832 g/m^2. Zebra mussels were identified at T10.

Table 11.12: Conneaut Lake – SAV Survey – Transect 11						
Conneaut Lake - T11 - 7/18/16						
Common	Species	20	40	60	80*	100
Yellow Pond-Lily	*Nuphar variegata*					A
Coontail	*Ceratophyllum demersum*					C
Elodea	*Elodea canadensis*			A	A	C
Eurasian Watermilfoil	*Myriophyllum spicatum*	C	P	A	A	C
Water Stargrass	*Heteranthera dubia*			P	P	P
Brittle Naiad	*Najas minor*		C	A	P	
Flat-Stem Pondweed	*Potamogeton zosteriformis*		P		C	
Vallisneria	*Vallisneria americana*			P	A	
Marsh marigold	*Megalondonta beckii*				P	
Slender Naiad	*Najas flexilis*	A	A			
Richardson's Pondwee	*Potamogeton richardsonii*		P			
White Waterlily	*Nymphaea odorata*	C	P			
Curly-Leaf Pondweed	*Potamogeton crispus*	Identified Off-Transect				
Zebra Mussel	*Dreissena polymorpha*	Not Present				

T11 was located at the northern end of the lake. Species richness and diversity as markedly elevated at this station with thirteen species identified. Non-native species at this station included Eurasian watermilfoil and curly-leaf pondweed. Eurasian watermilfoil was the most dominant species followed by elodea and slender naiad. Biomass values at T11 were the highest of all sampled stations with a measure of 9,252 g/m^2. Zebra mussels were not identified at this station.

Table 11.13: Conneaut Lake – SAV Survey – Transect 12						
Conneaut Lake - T12 - 7/18/16						
Common	Species	20	40*	60	80	100
Vallisneria	*Vallisneria americana*	A	A	C	C	A
Richardson's Pondweed	*Potamogeton richardsonii*	P				C
Fanwort	*Cabomba caroliniana*					P
Coontail	*Ceratophyllum demersum*		P			
Thin-Leaf Pondweed	*Potamogeton pusillus*	C				
Zebra Mussel	*Dreissena polymorpha*	Not Present				

Transect 12 was located in the northeast portion of the lake near T11. Species richness at T12 was lower than that of T11 with five species identified. *Vallisneria* was the dominant species in terms of biomass followed by Richardson's pondweed. Total macrophytes biomass at T12 was markedly lower than that measured at T11 with a total biomass of 630 g/m^2. As with T11, no zebra mussels were identified at T12.

Table 11.14: Conneaut Lake – SAV Survey – SAV / Zebra Mussel Biomass

Transect	Biomass (g/m2)
1	265
2	1,895
3	500
4	2,094
5	6,084
6	8,130
7	4,599
8	308
9	728
10	832
11	9,252
12	630
Min	265
Max	9,252
Mean	2,943

A summary of macrophyte biomass, collected at one representative station along each transect, for all 12 transects is presented above (Table 11.14). Plant biomass ranged from 265 g/m^2 to 9,252 g/m^2 with a mean biomass of 2,943 g/m^2. Plant biomass was extremely variable throughout the lake at the time of sampling with a standard deviation of 3,246 g/m^2.

It is recommended that CLAMA consider the formation of a citizen Weed Warrior program to continue to monitor vegetation, especially exotic and invasive vegetation. Weed Warrior programs have been successful in detecting new invasive plant infestations before they become a problem. Weed Warrior programs can be as simple as a training of volunteers on potential problem species with a central reporting point, or as complex as full vegetation inventory. It is also recommended that the local municipalities and CLAMA consider partnering to implement a launch steward program at each of the public access points on the lake. Launch Steward programs have been proven to be successful at detecting problem invasive species before they enter a waterbody.

12.0 Water Quality Summary

12.1 Introduction & Methodology

Water quality monitoring of Conneaut Lake is an integral component of this WIP as it provides an update on the trophic state of the lake. Furthermore, this data will be utilized to describe any current water quality impairments and may be used as a baseline dataset upon which improvements in water quality may be detected as watershed projects detailed in this plan are implemented.

All water quality monitoring was conducted by the Crawford County Conservation District with laboratory analysis provided by PADEP. Sampling was conducted on 30 April 2015, 14 July 2015, 27 October 2015, 25 April 2016, 20 July 2016, 4 August 2016, 23 August 2016, 22 September 2016, 2 November 2016, 9 May 2017, 26 June 2017 and 26 September 2017. Sampling was conducted in the surface and deep waters of three stations: Station 1 – Mid Lake, Station 2 – South End Outlet, and Station 3 – North End. At each station, the CCSWCD measured *in-situ* temperature, specific conductance, pH and dissolved oxygen at 1 m intervals. Transparency was measured with Secchi disk. Also, discrete samples were collected for laboratory analysis. Surface and deep water samples were analyzed for a full suite of water quality parameters, the details of which can be seen in Appendix III. For this analysis, Princeton Hydro isolated the following parameters at station 1 as these are the most germane to understanding the trophic state of Conneaut Lake: Chlorophyll *a* (Chl), total nitrogen (TN), total phosphorus (TP), total orthophosphorus (TOP), dissolved phosphorus (DP), and total suspended solids (TSS). Finally, the plankton community at each station was analyzed for community composition and abundance.

12.2 Results

The following section will briefly discuss the results of the water quality monitoring conducted as part of this WIP. An extensive dataset was collected on numerous parameters in several stations to completely describe the water quality of the lake over a period of three years (2015-2017). This section will briefly discuss those *in-situ*, discrete laboratory and plankton results at ST-1 as they relate to the trophic state of the lake.

12.2.1 In-situ Data

Temperature and dissolved oxygen profiles, as measured at Station 1 (Deep station) are provided in figures 12.1 through 12.6 below.

Figure 12.1: Conneaut Lake – 2015 Temperature Distributions (ST-1)

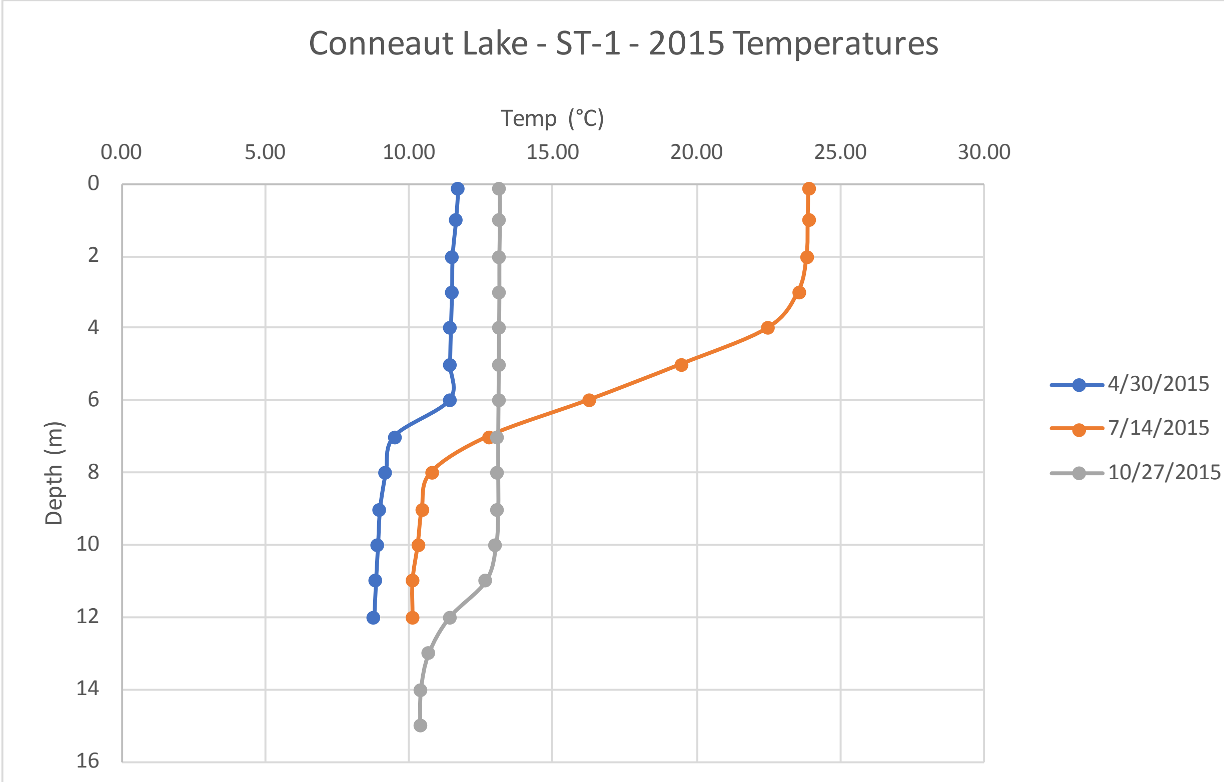


Figure 12.2: Conneaut Lake – 2016 Temperature Distributions (ST-1)

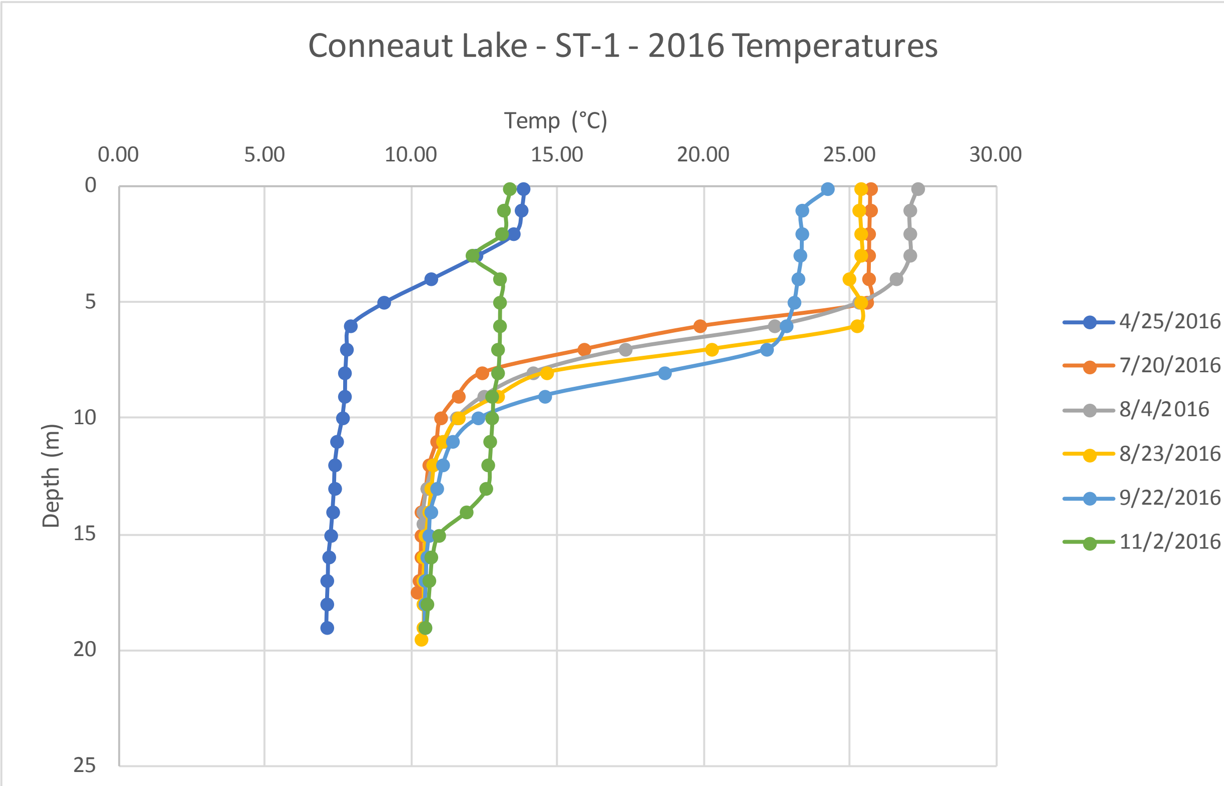
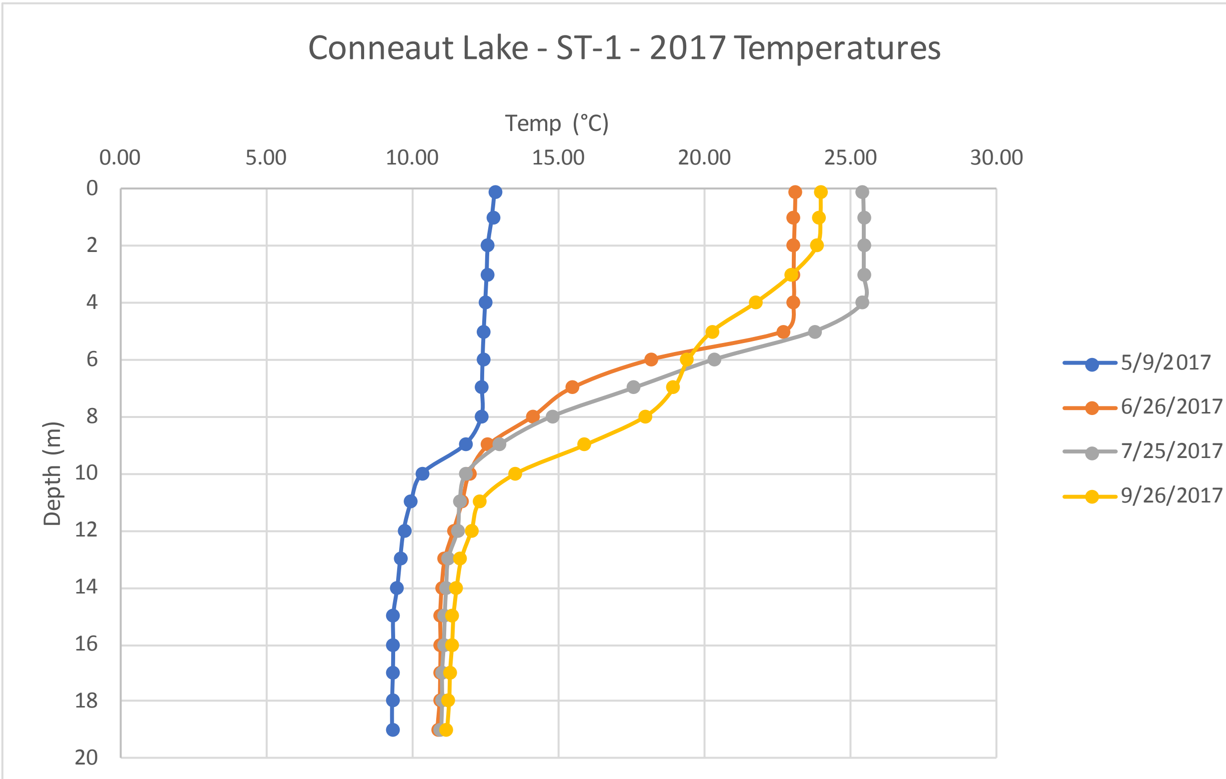


Figure 12.3: Conneaut Lake – 2017 Temperature Distributions (ST-1)



The lake became thermally stratified by the April / May events with strong thermal stratification existing between the July and late-September sampling events with almost full mixing by November. Thermal stratification resulted in stratification of dissolved oxygen as shown in figures 12.4 – 12.6 below.

Figure 12.4: Conneaut Lake – 2015 Dissolved Oxygen Distributions (ST-1)

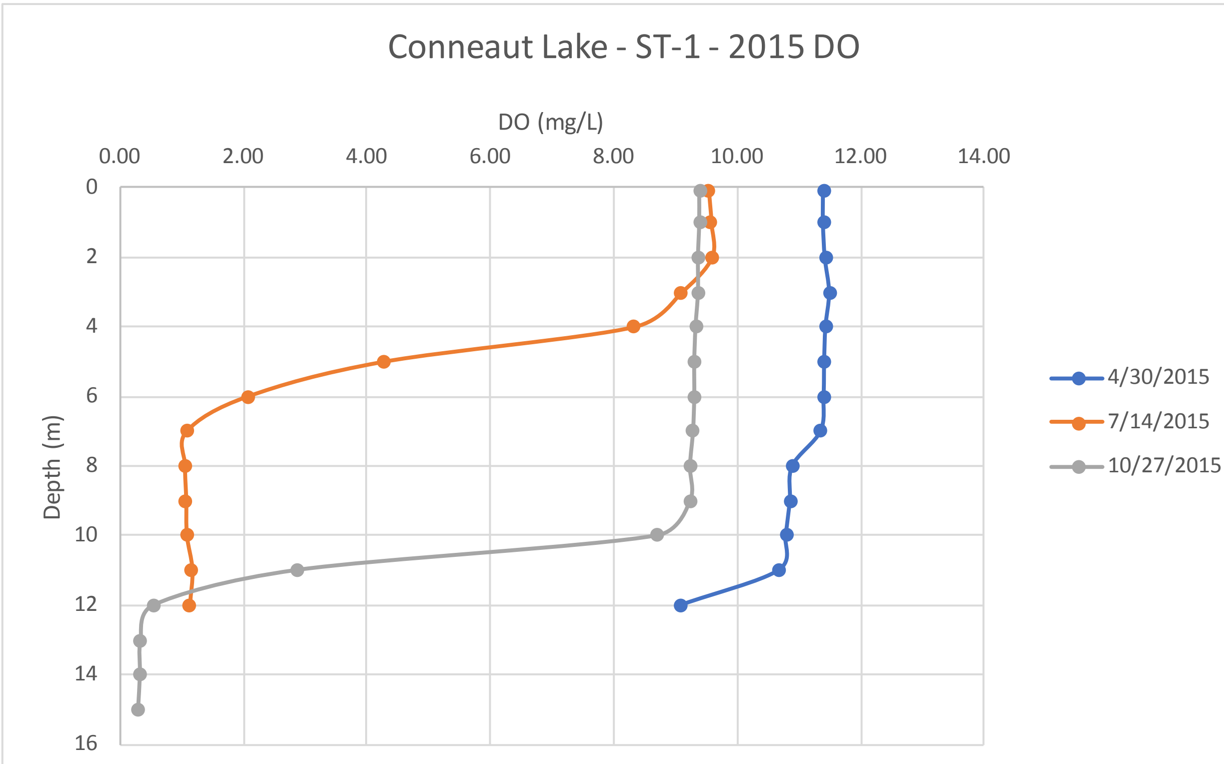


Figure 12.5: Conneaut Lake – 2016 Dissolved Oxygen Distributions (ST-1)

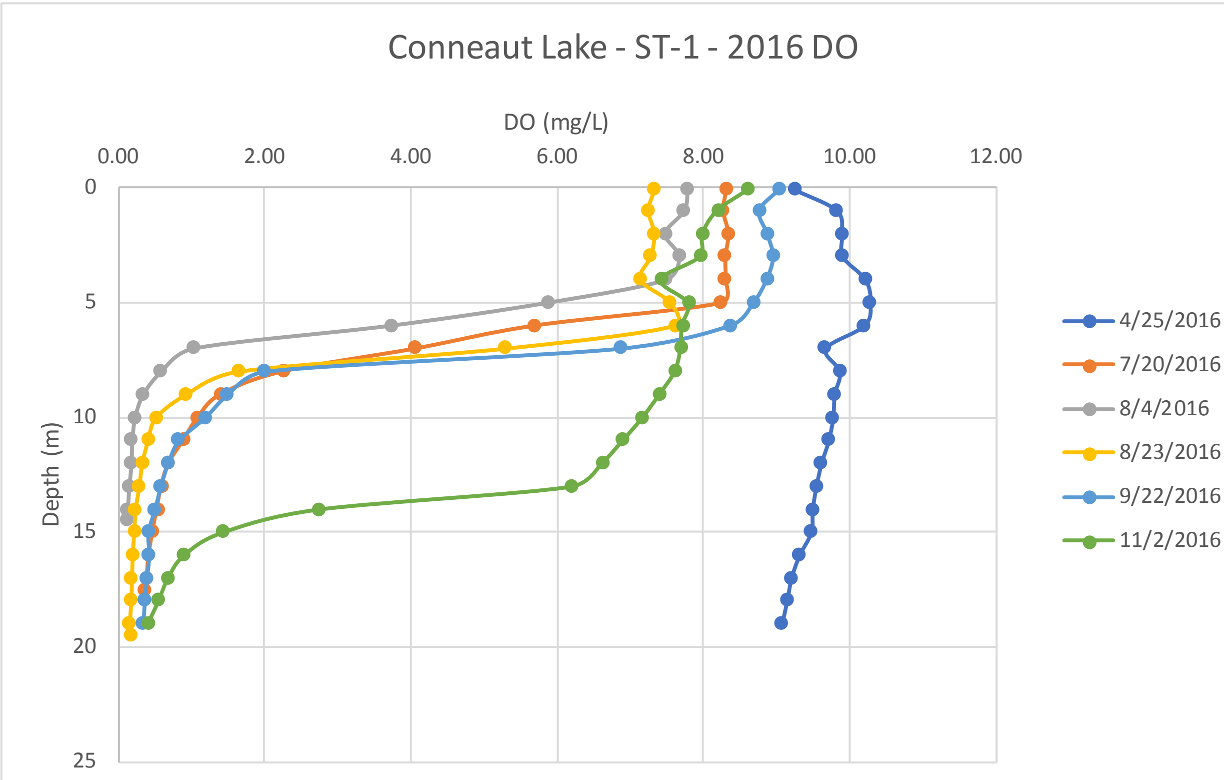
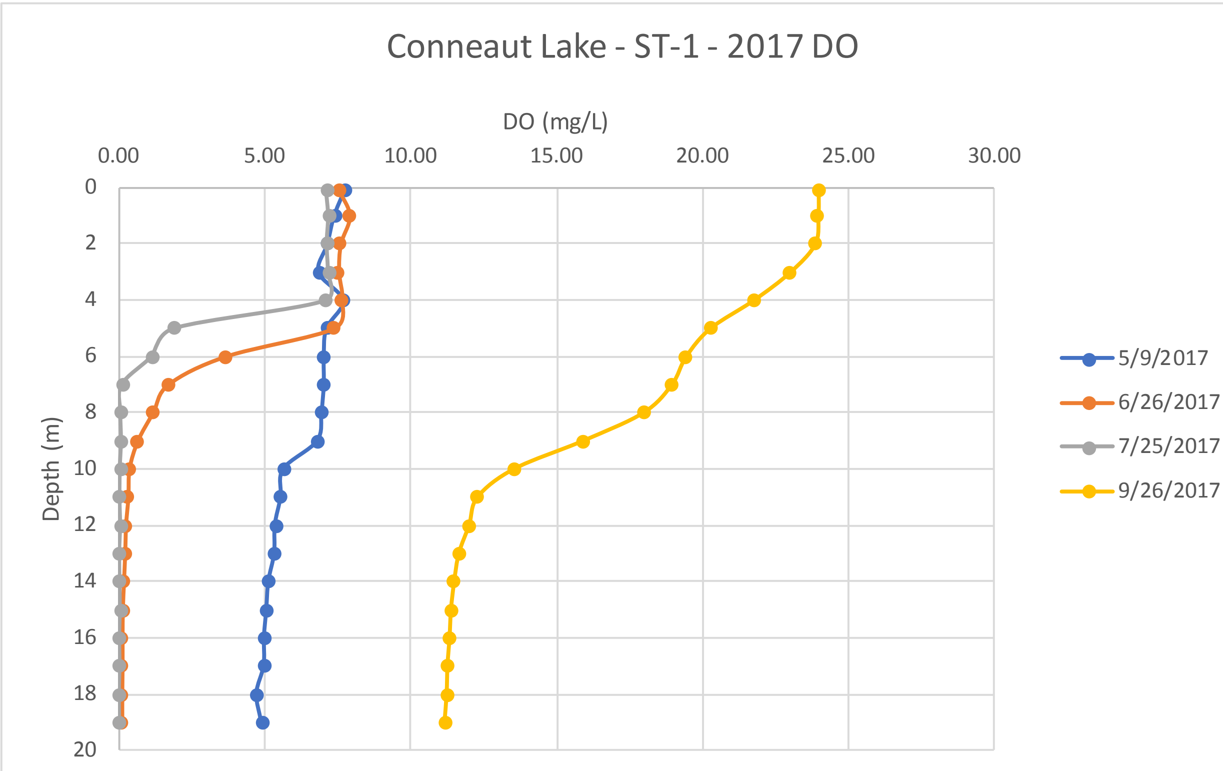


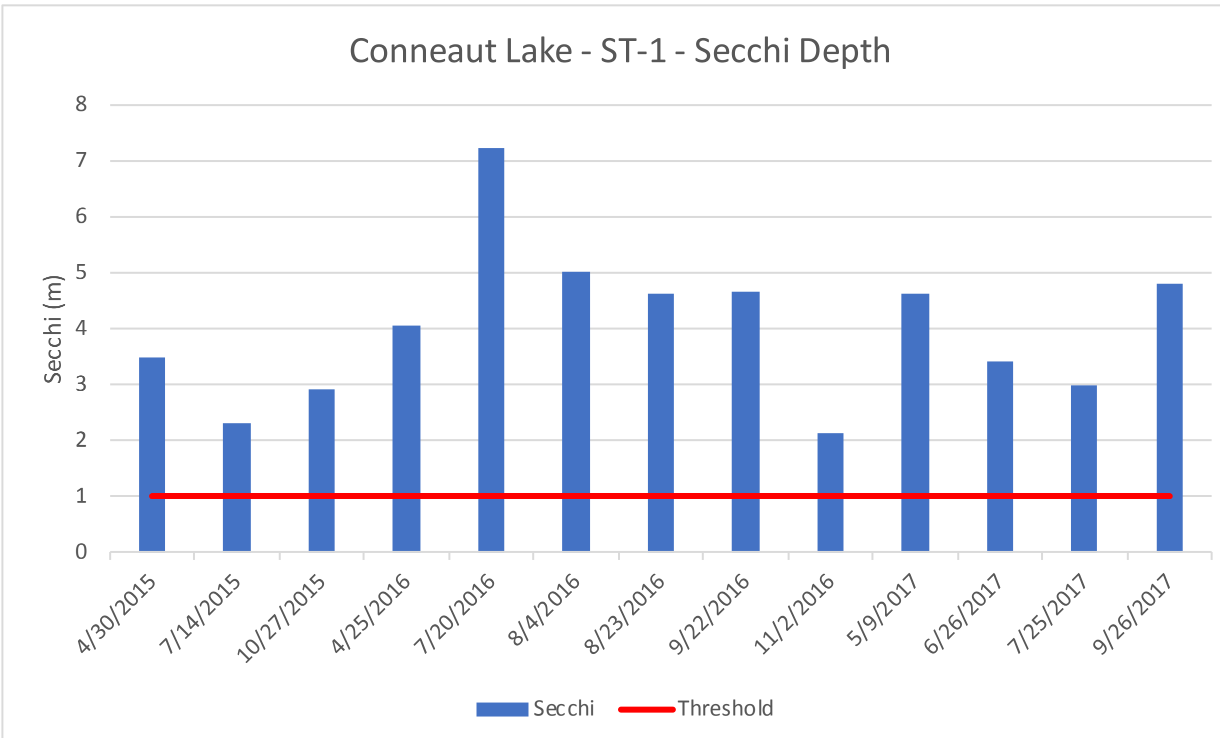
Figure 12.6: Conneaut Lake – 2017 Dissolved Oxygen Distributions (ST-1)



Strong stratification of dissolved oxygen is evident in 2015, 2016 & 2017 with anoxia developing in the hypolimnion. Anoxic conditions were noted in 2016 from approximately 10 m to the bottom (Z_{max} = 19.5 m) while stronger anoxic conditions were noted in 2017, extending from 7 m to the lake bottom.

Secchi disk transparency at the lake was routinely elevated with 2015-2017 measures ranging from 2.1 m to 7.2 m. Overall Secchi disk measures at ST-1 are hereby presented in Figure 12.7.

Figure 12.7: Conneaut Lake – ST-1 Secchi Depth



12.2.2 Discrete Laboratory Data

Total phosphorus measures were recorded in the surface and deep waters of ST-1 while additional measures were made for dissolved phosphorus (bottom samples on 4/30/15 & 7/14/15) and total ortho-phosphorus (7/20/16 through 9/26/17). Surface and deep-water TP data is hereby presented in Figures 12.8 through 12.9.

Figure 12.8: Conneaut Lake – ST-1 Surface TP

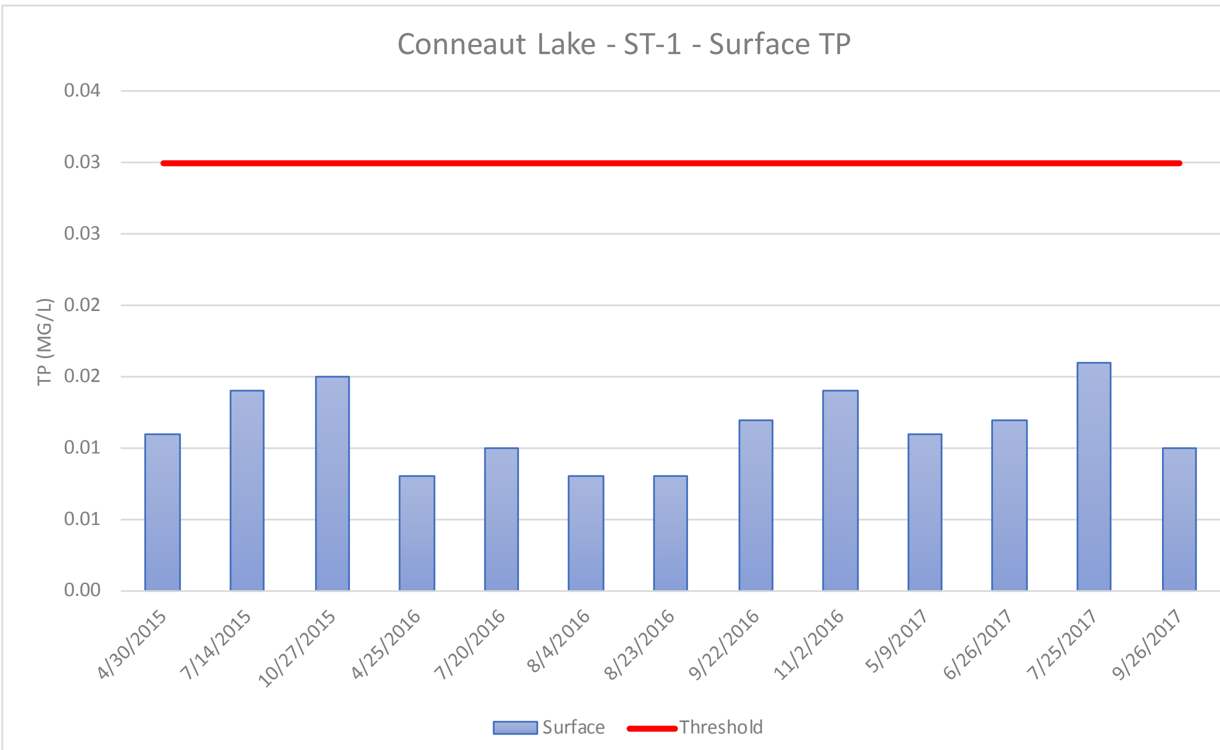
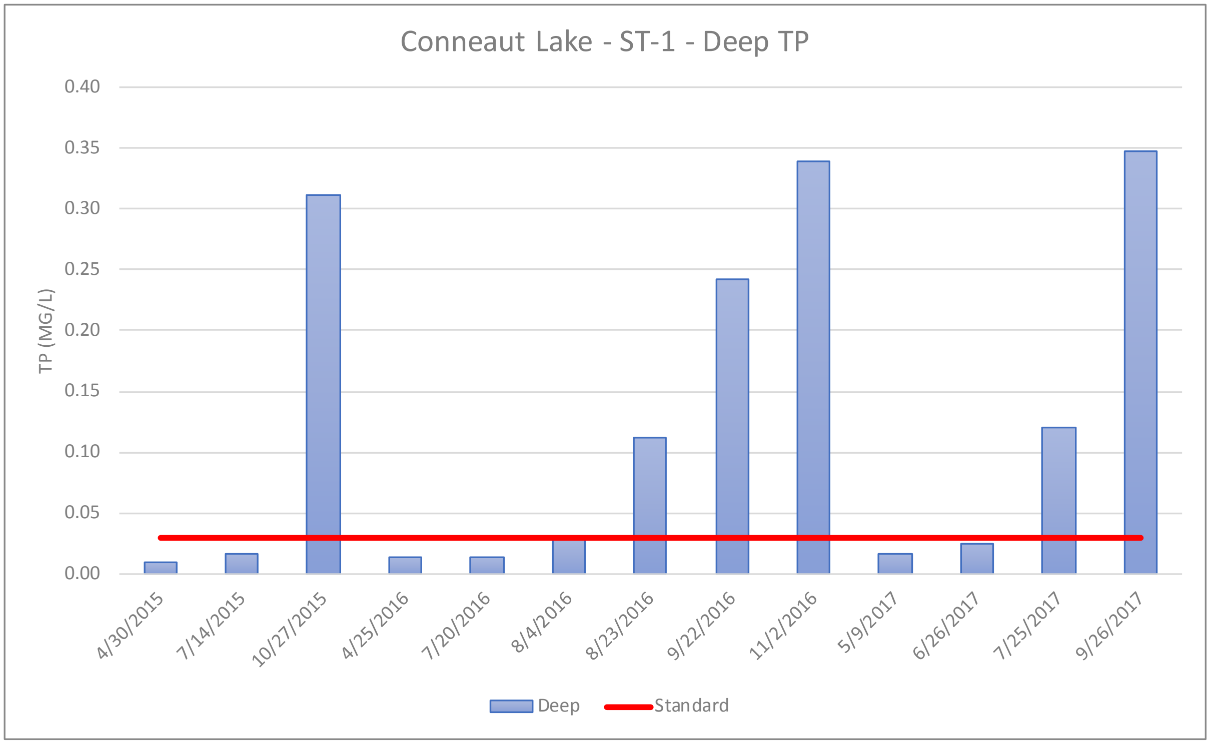


Figure 12.9: Conneaut Lake – ST-1 Deep TP



As shown above, surface water TP concentrations were routinely low with no value exceeding the recommended threshold of 0.03 mg/L. In contrast, deep water TP concentrations were routinely elevated with excessive deep water TP noted in October 2015. Furthermore, with development of hypolimnetic anoxia in 2016 there was a concomitant increase in hypolimnetic TP with measures reaching 0.34 mg/L in November 2016. A similar pattern was reproduced in 2017 although the intensity was greater due to increasing hypolimnetic anoxia. Deep water TP measures at ST-1 in 2017 reached a maximum of 0.35 mg/L in September.

Total nitrogen to total phosphorus concentrations were compared to assess the ratio of these two important nutrients. Typically, TN:TP ratios less than 10 are indicative of nitrogen limitation, values between 10 and 17 may indicate nitrogen or phosphorus limitation while values greater than 17 are indicative of phosphorus limitation. Oftentimes total inorganic nitrogen (TIN) is compared to total phosphorus as the majority of organic, particulate nitrogen does not factor in algal photosynthesis. Since nitrate measures were not taken the TN:TP ratio is presented here (Figures 12.10 & 12.11).

Figure 12.10: Conneaut Lake – Surface TN:TP

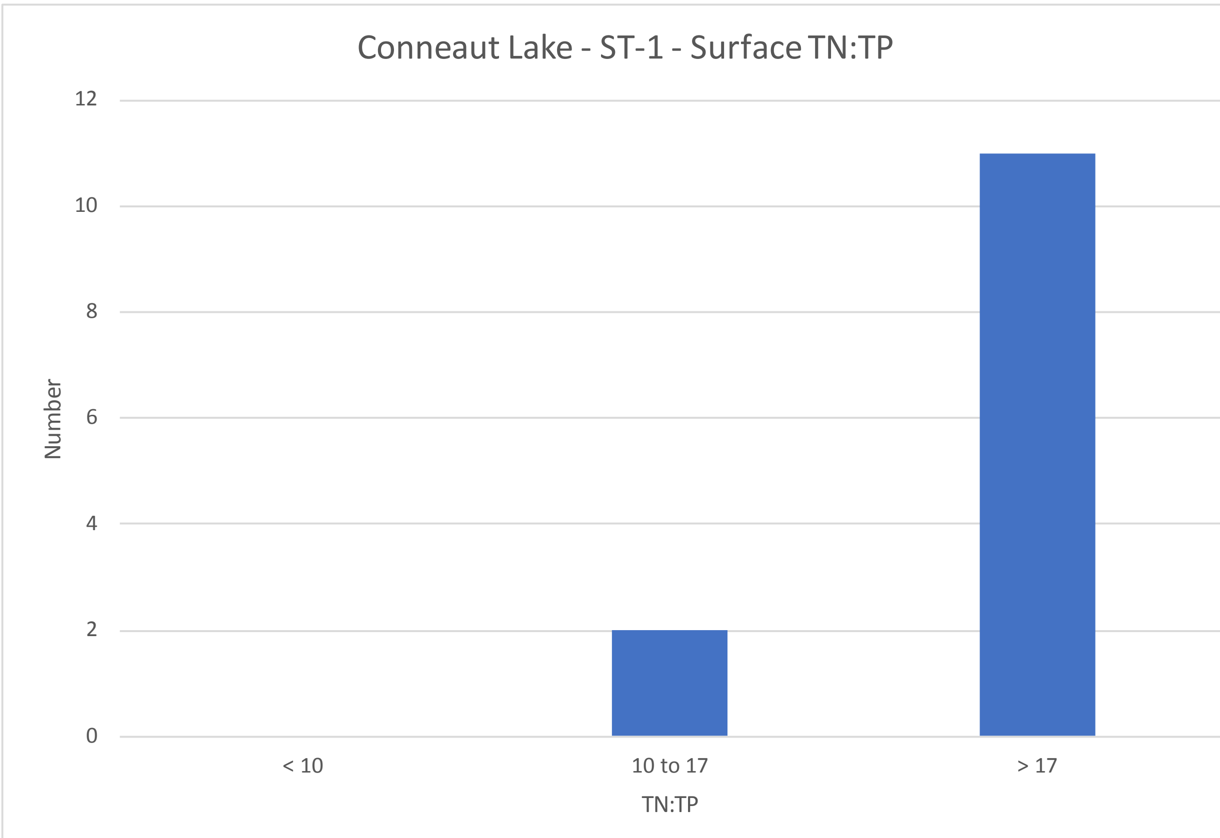
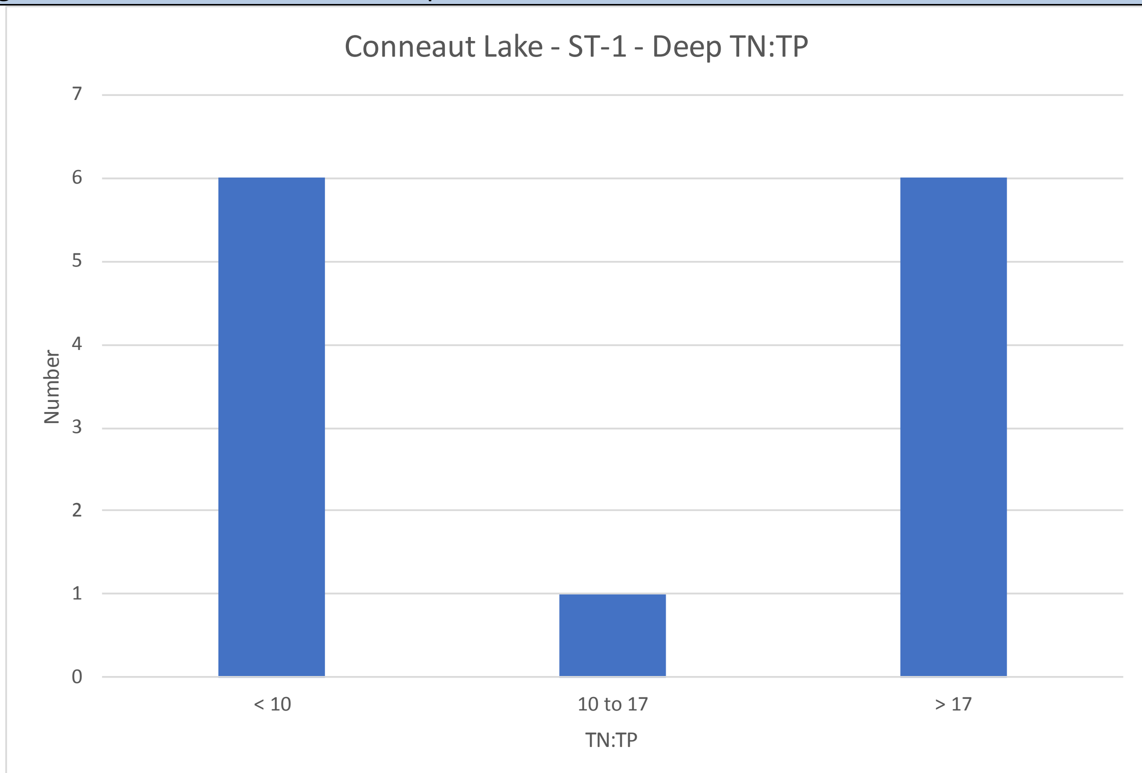


Figure 12.11: Conneaut Lake – Deep TN:TP



As shown above, surface water measures of ST-1 are strongly indicative of P limitation. Ratios in the deep waters were more variable equal instances of measure below 10 (nitrogen limitation) and greater than 17 (phosphorus limitation).

Chlorophyll *a* measurements at ST-1 were variable throughout the three-year dataset with measures ranging from 1.1 µg/L in November 2016 to 25.34 µg/L in June 2017. Two events in 2017 showed chlorophyll *a* measures greater than 20 µg/L while the highest measure in 2015 and 2016 combined was 6.22 µg/L.

12.2.3 Plankton Data

Plankton data for station 1 was presented for the following dates: 30 April 2015, 14 July 2015, 27 October 2015, 25 April 2016, 20 July 2016, 4 August 2016, 23 August 2016 and 26 June 2017. Overall, the algal community was comprised of diatoms, particularly during the Spring sampling as would be expected due to cool water temperatures. During the summer months, diatoms were still prevalent as were the cyanobacteria and, to a lesser extent, the chlorophytes. The cyanobacteria *Aphanizomenon* was dominant during the 20 July 2016 event while *Anabaena, Aphanocapsa, Coelosphaerium, Microcystis,* and *Lyngbya* were all also identified in lower densities. *Anabaena* was present in moderate densities during the 23 August 2016 event while *Aphanizomenon* was dominant on 22 September 2016. The dominant alga during the May 2017 event was the cyanobacteria *Phormidium*.

12.3 Trophic State

Carlson's Trophic State index is a commonly used tool by lake managers to assess lake productivity and to track changes in eutrophication over time. Carlson's Trophic Index is a log based, single variable trophic index that uses chlorophyll *a* concentration, total phosphorus concentration, or Secchi depth to calculate an index value, from 0 to 100, to designate the productivity status of a lake.

The index was calculated by Dr. Robert Carlson through the use of regression equations on a robust dataset of North American lakes. The basic assumptions of this index are that suspended particulate matter is the primary determinant of Secchi depth and that algal particles are the sole source of this suspended matter. Given these assumptions TSI values calculated for chlorophyll *a*, total phosphorus and Secchi disk should all be equal. Frequently they are not and systematic differences in productivity may therefore be determined through residuals analysis.

Index values greater than 50 are generally associated with eutrophic conditions and are correlated with chlorophyll *a* concentrations of 7.3 µg/L and greater. Tracking TSI values over time may provide great insight as to the rate of lake eutrophication and the benefits of management measures which serve to reduce excessive algal growth.

Carlson's TSI for surface and deep TP, chlorophyll *a*, and Secchi depth are presented in Table 12.1 below.

Table 12.1: Carlson's TSI – ST-1 – 2015 – 2017 Average Data

Conneaut Lake – ST-1 TSI Mean 2015-2017			
Surface TP	Deep TP	Chl a	Secchi
39	74	50	40

Carlson's TSI value for total phosphorus was variable based on water depth with a measure correlating with the upper-end of oligotrophy in the surface contrasting with a measure associated with hypereutrophy from the deep-water measures. TSI index values for Secchi were lower than those for chlorophyll *a*. The former was associated with eutrophy while the latter is associated with mesotrophy.

One of the drawbacks of assessing trophic state utilizing the TSI is that it only accounts for chlorophyll *a* contained in planktonic algae. As such, this measure does not inherently address primary productivity which occurs primarily from macrophytes as is the case for Conneaut Lake. Furthermore, this issue becomes confounded in Conneaut due to the prevalence of zebra mussels which alter phytoplankton densities and clarity which is the likely reason for a lower than expected Secchi TSI. Nevertheless, the TSI may be useful in evaluating the long-term productivity of Conneaut Lake in concert with select sampling of macrophyte biomass and distributions.

13.0 Summary

Princeton Hydro, in concert with the Conneaut Lake Aquatic Management Association and the Crawford County Conservation District, conducted a watershed implementation plan for Conneaut Lake. The WIP conducted herein conforms to the nine (9) essential elements required by the USEPA as it serves to update the pollutant load, identify sources of impairment and best management practices to correct this impairment, describes the financial assistance needed to implement the BMPs and provides outreach, monitoring and timetable elements.

The TMDL has provided a target for total phosphorus reduction from watershed sources of 479 lbs/yr. The past watershed projects implemented by the CCCD were estimated to remove approximately 26.8 lbs of TP or 5.6% of that load targeted for reduction. The past projects, in concert with the BMPs recommended as part of this WIP, are estimated to remove 77.5% of the annual, watershed based TP load targeted for reduction. As such, additional watershed work will need to be identified to target additional areas for the removal of the remaining 22.5%.

The implementation schedule for this WIP calls for the identified projects to be carried out over an approximately fifteen-year period. In total, the projects are estimated to cost between $2.6 to $5.545 million dollars with annual maintenance costs ranging from $24,450 to $70,000 per year. Funding for the implementation of these projects should be sources from Non-point source 319 funds, PA Growing Greener funds, or similar. Continued monitoring of the lake, and the functionality of any implemented BMPs, should occur to track progress over time. Furthermore, the WIP should be updated as plans evolve and change.

Control of internal phosphorus sources should continue through harvesting of macrophytes. In addition, once numerous watershed based projects are completed, Conneaut Lake should receive nutrient inactivation through the use of alum or similar inactivation products to inactivate internal loading of phosphorus from the sediments.

Efforts to implement the recommendations of this plan should come from within the Conneaut Lake community. Only with strong local leadership can the goal of improving the water quality of the lake, and thus preserving or improving property values and quality of life around the lake be realized. Local leadership should come from Conneaut Lake Aquatic Management Association, Conneaut Lake Borough, Sadsbury Township, and Summit Township. Support for these efforts can come from sources such as Crawford County Conservation District, Crawford County Planning Commission, French Creek Valley Conservancy, Western PA Conservancy, as well as other similar organizations.

Finally, it should be emphasized that this WIP is a planning document and more, site specific information is required in order to ultimately determine project feasibility. This information should include, but is not limited to, topographic and property boundaries, existing easements and right-of-ways, and existing soil and groundwater characteristics. The overall goal of this WIP is to provide guidance in the selection, design and implementation of cost-effective projects that will reduce watershed based phosphorus loading to Conneaut Lake.

14.0 References

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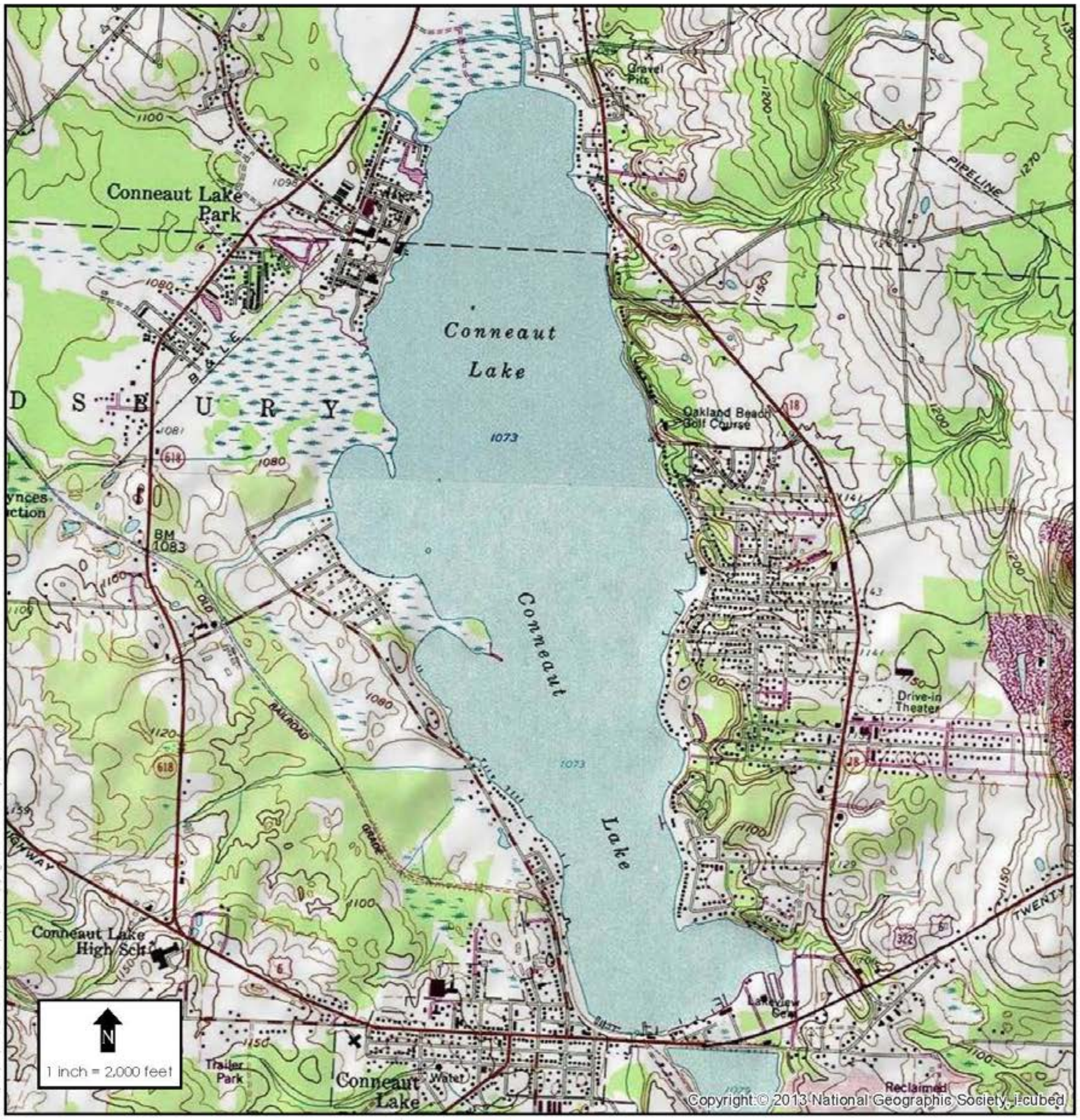
Appendix I

Project Figures



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Map Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet

SITE LOCATION MAP

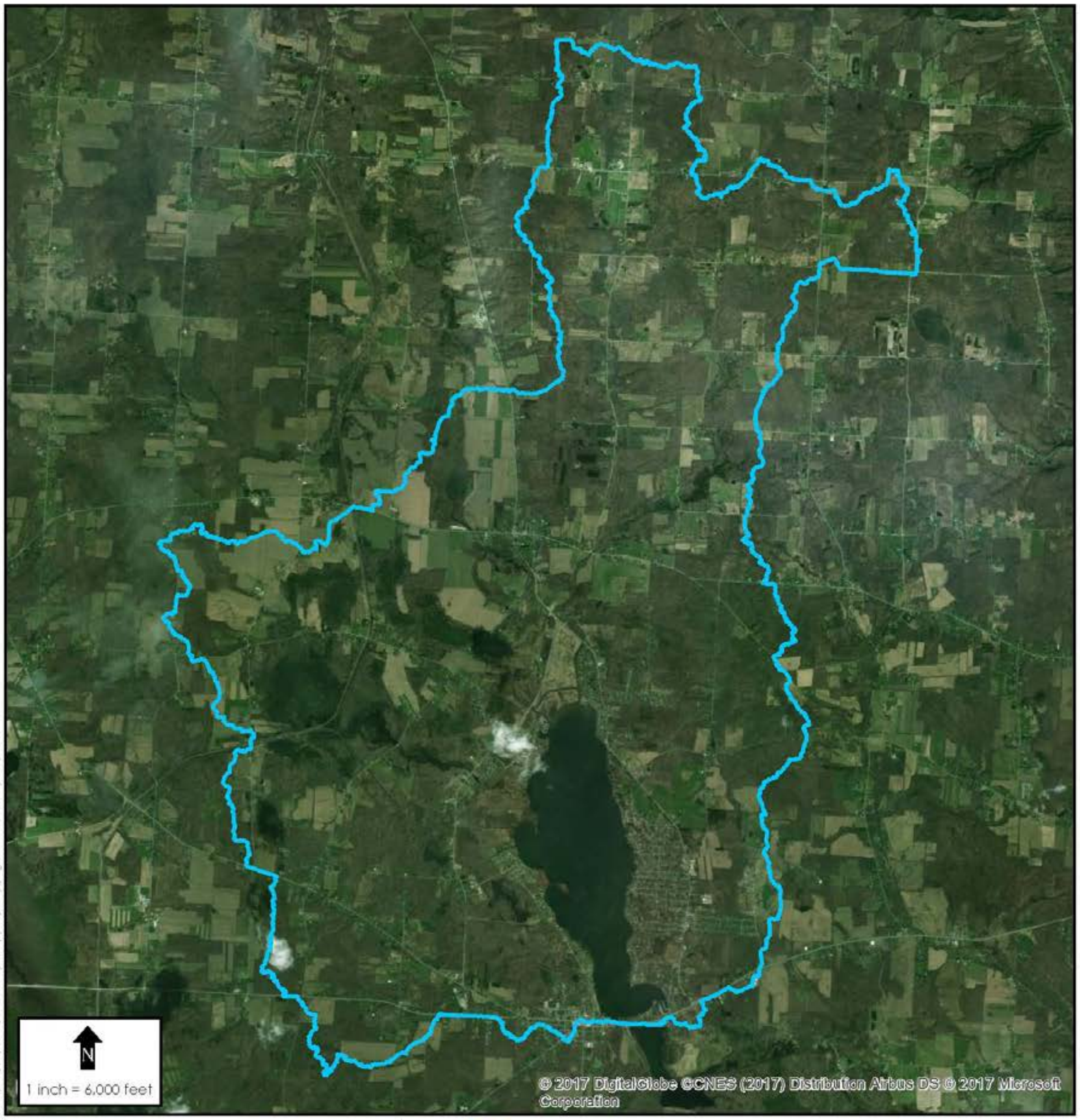
CONNEAUT LAKE
GROWING GREENER GRANT
SADSBURY TOWNSHIP
CRAWFORD COUNTY, PA

LEGEND

PRINCETON HYDRO, LLC.
203 EXTON COMMONS
EXTON, PA, 19341
*with offices in NJ, PA and CT

NOTES:

PENNSYLVANIA COUNTY MAP



WATERSHED BOUNDARY MAP

CONNEAUT LAKE
GROWING GREENER GRANT
SADSBURY TOWNSHIP
CRAWFORD COUNTY, PA

LEGEND

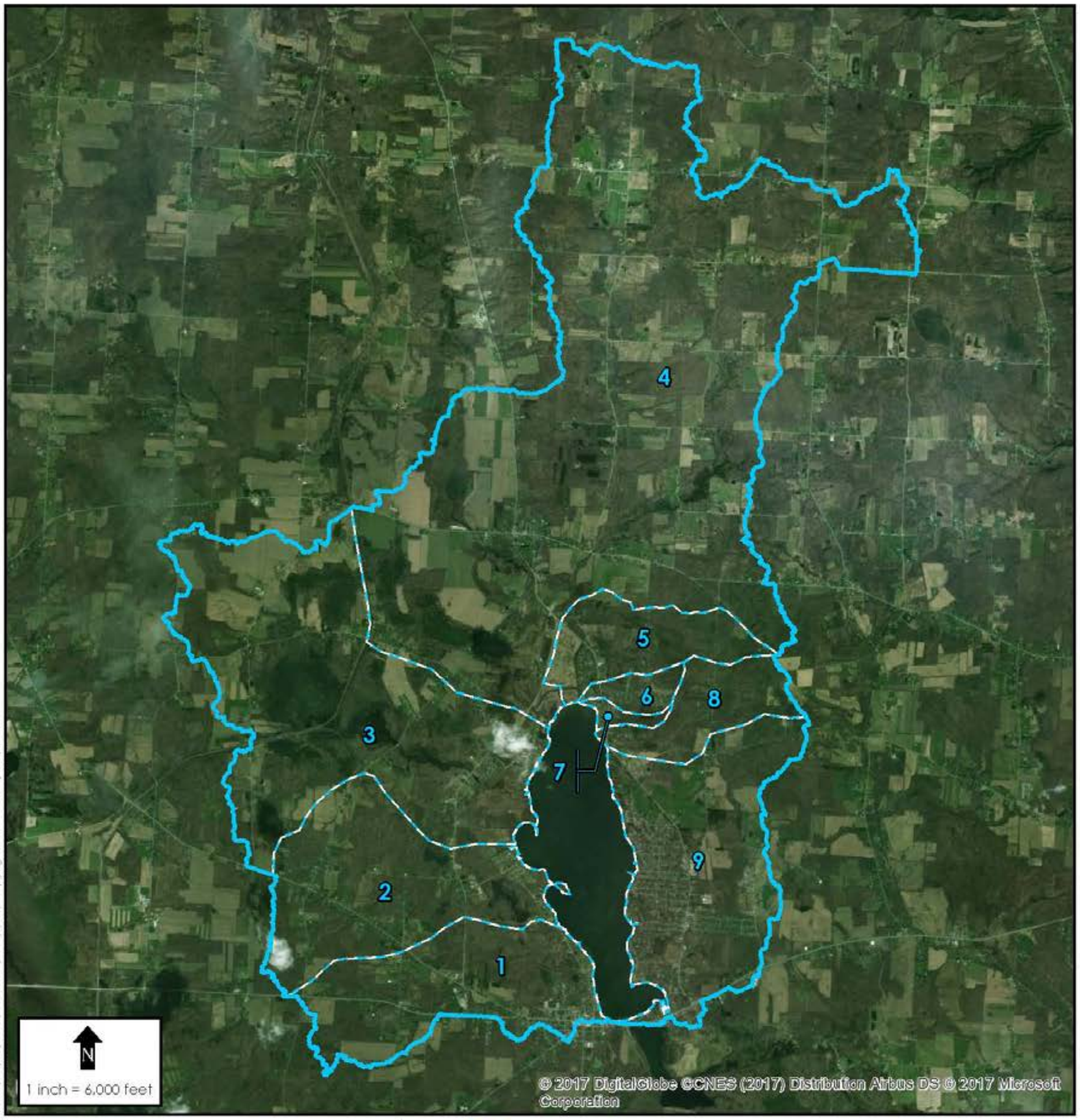
Watershed Boundary

PRINCETON HYDRO, LLC.
203 EXTON COMMONS
EXTON, PA, 19341
*with offices in NJ, PA and CT

NOTES:

Watershed boundary delineated by Princeton Hydro utilizing ArcGIS and Lidar data

PENNSYLVANIA COUNTY MAP



SUBWATERSHED BOUNDARY MAP

CONNEAUT LAKE
GROWING GREENER GRANT
SADSBURY TOWNSHIP
CRAWFORD COUNTY, PA

LEGEND

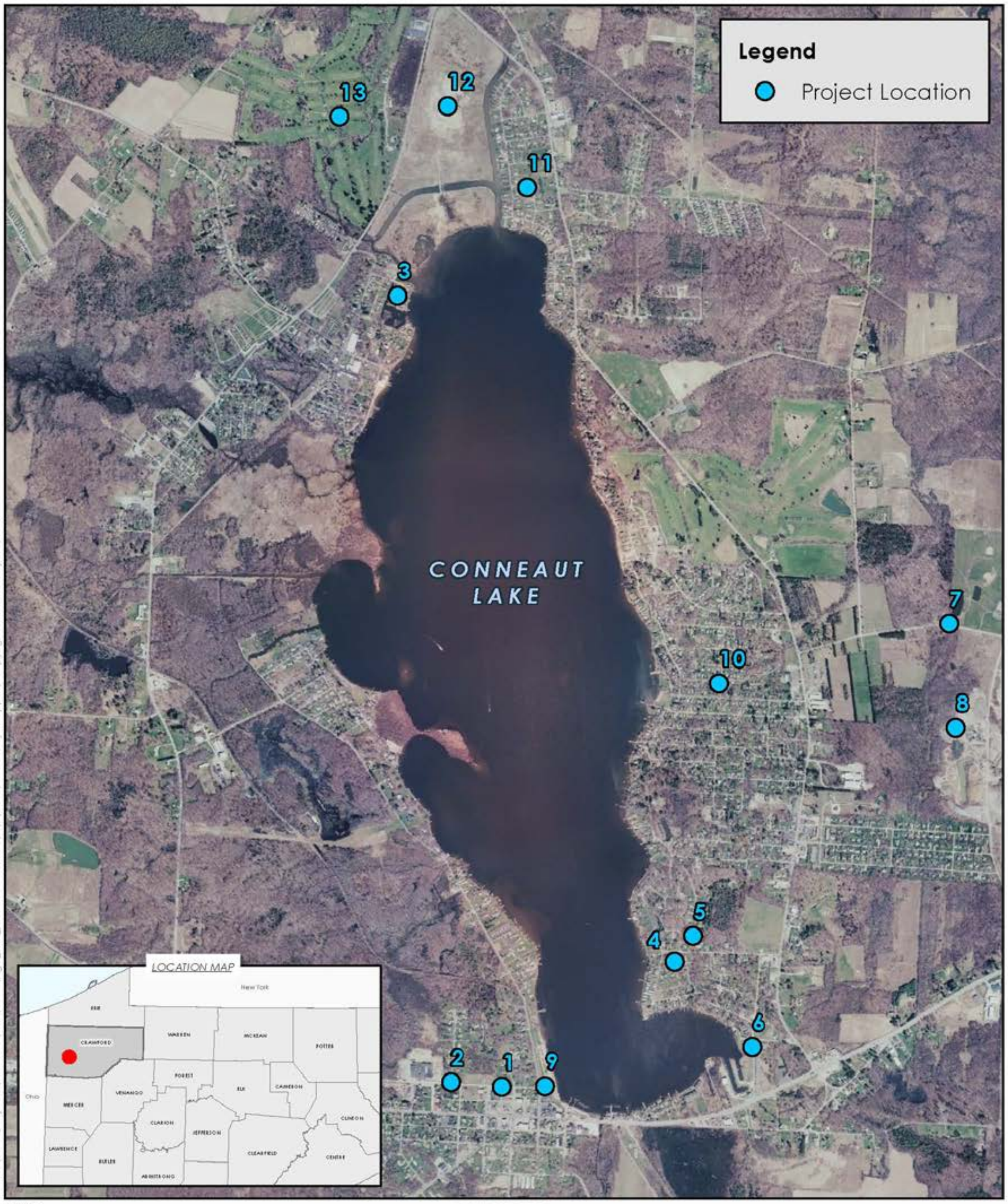
Watershed Boundary
Subwatershed Boundary

PRINCETON HYDRO, LLC.
203 EXTON COMMONS
EXTON, PA, 19341
*with offices in NJ, PA and CT

NOTES:

Watershed boundary delineated by Princeton Hydro utilizing ArcGIS and Lidar data

PENNSYLVANIA COUNTY MAP



NOTES:
1. Project locations are approximate.
2. Municipal boundaries and 2005 aerial imagery obtained from the Pennsylvania Spatial Data Access (PASDA) website: http://www.pasda.psu.edu/

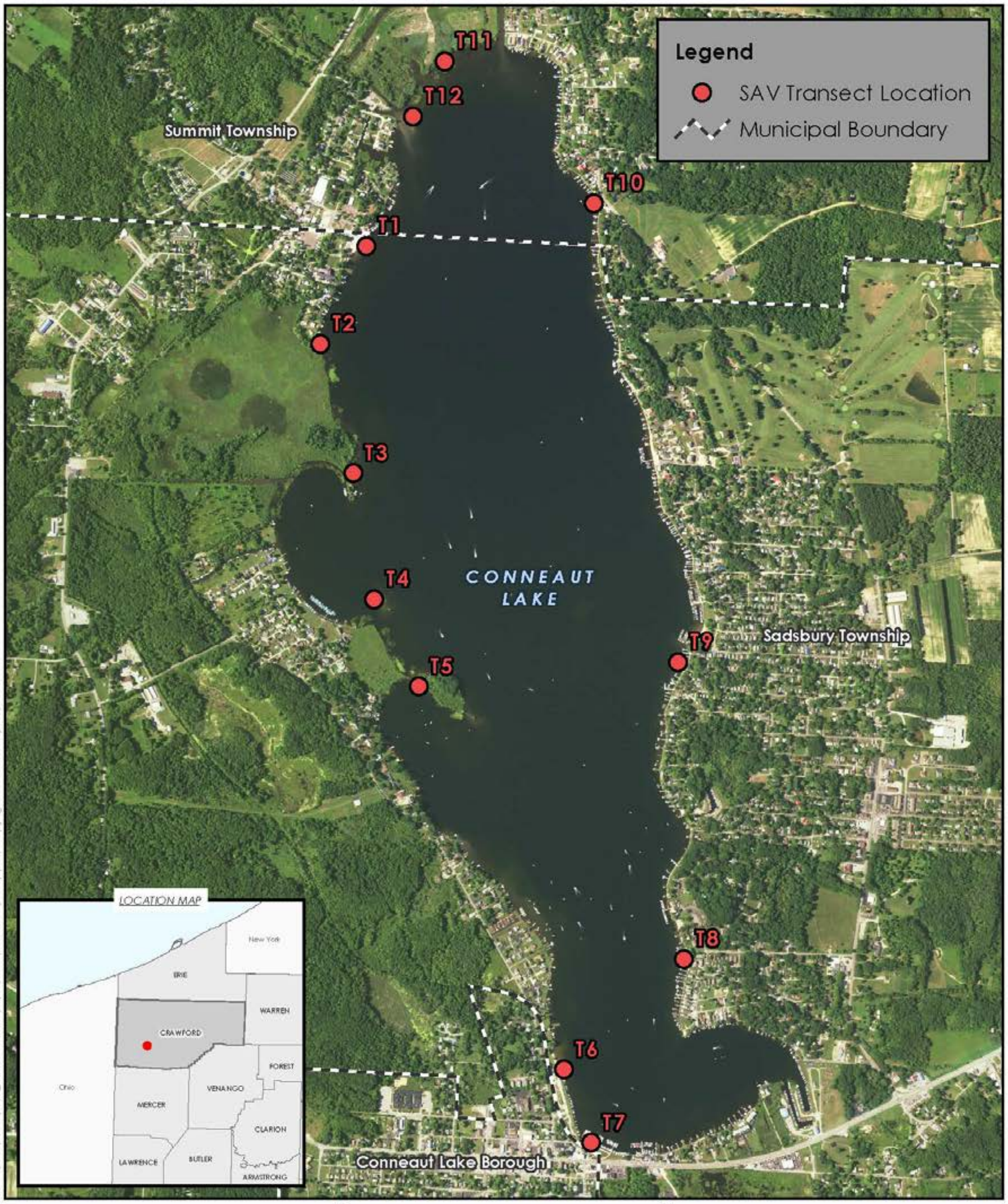
0 1,000 2,000 Feet

Map Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet

FIGURE 2:
WATERSHED IMPLEMENTATION PLAN

CONNEAUT LAKE
GROWING GREENER GRANT
SADSBURY TOWNSHIP
CRAWFORD COUNTY, PENNSYLVANIA

PRINCETON HYDRO
SCIENCE DESIGN ENGINEERING
www.PrincetonHydro.com



SAV TRANSECT LOCATIONS

CONNEAUT WATERSHED IMPLEMENTATION PLAN
CRAWFORD COUNTY CONSERVATION DISTRICT
SUMMIT & SADSBURY TOWNSHIPS
CRAWFORD COUNTY, PENNSYLVANIA

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. SAV transect locations are approximate. SAV study perfomed by Princeton Hydro, LLC.
2. Municipal boundaries obtained from the Pennsylvania Spatial Data Access (PASDA).
3. 2015 orthoimagery obtained from the United States Department of Agriculture's (USDA), National Agriculture Imagery Program (NAIP).

0 800 1,600 Feet

Map Projection: NAD 1983 StatePlane Pennsylvania North FIPS 3701 Feet

Appendix II

Phase I & TMDL

Appendix III

Water Quality Data